The APRIL, 1933

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Heating · Piping and Air Conditioning

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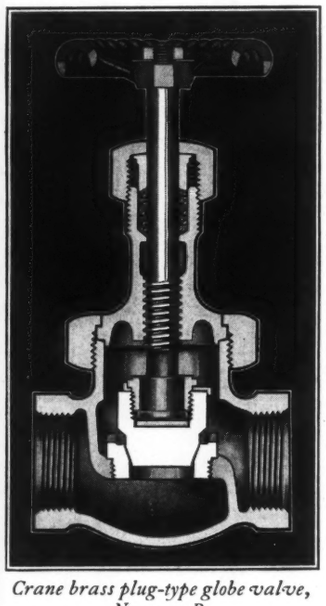

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Heating · Piping and Air Conditioning

THE EDITOR'S PAGE

PIPING is finding another bright place in the sun of plant operation and production with the increased manufacturing activity created by the legalization of beer. The making of beer is primarily a cooking and cooling process—high-and low-pressure steam, hot and cold water, refrigeration, compressed air are used. In their proper application, piping is of course essential, as well as in the handling of the wort and beer itself. The description of the piping services in the Atlas Brewing Company plant in this issue will give the reader a clear idea of the place of piping in the brewing of beer.

HEATING a group of school or institutional buildings from a central plant efficiently and economically requires careful engineering study of the many factors involved. Particularly is this true when the buildings are of various ages and are equipped with several different types of heating systems—usually the case. In his article starting this month Alfred Kellogg describes the working up of a complete program for heating a school or institutional group by steam from a central plant. The author is well known as a consulting engineer and is a member of our Board of Consulting and Contributing Editors. You will find his article authoritative, logically arranged, and clearly written.

AIR conditioning has developed to such a point that buildings without it find themselves penalized. Such was the situation confronting the 17-year-old Heard office building in Phoenix, Arizona—so they modernized with air conditioning.

Space being extremely limited it was found necessary to locate much of the air-conditioning equipment on the roof. From the first day of operation, complete operating records have been kept and these are analyzed and explained by Ralph E. Phillips in an article to be published in an early issue. Watch for it.

TIMELY is R. C. Doremus' article in this issue on modernizing refrigeration piping. Summer means increased refrigeration load and it will pay most plant engineers to check their refrigeration piping systems to be in readiness for economical and proper operation.

NOT only is drying of solids influenced by air temperature, humidity and motion but by the manner and rate moisture moves through the material being dried. Research at Massachusetts Institute of Technology on industrial drying furnishes the information given in the article by T. K. Sherwood and E. W. Comings in this number.

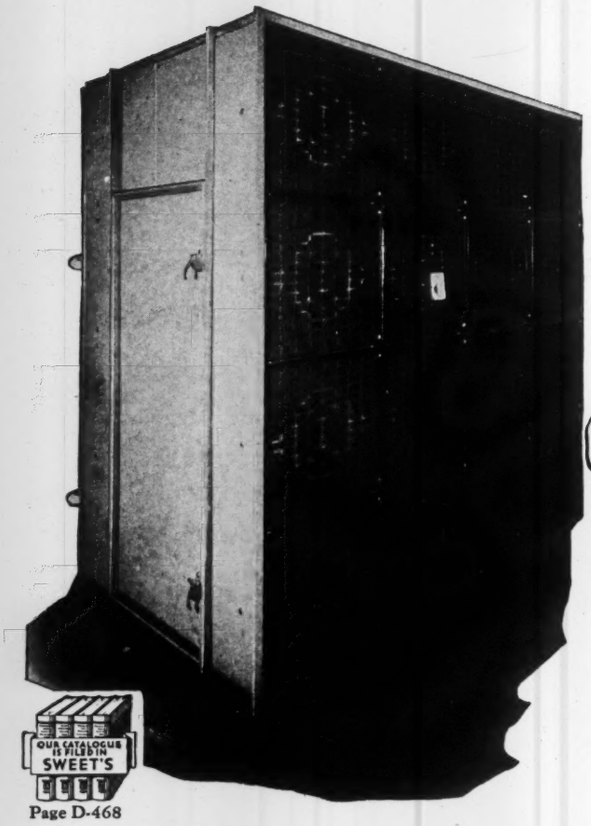

Illustration at left shows typical Dustop Air Filter bank installation.

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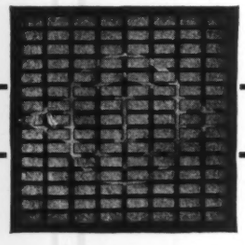

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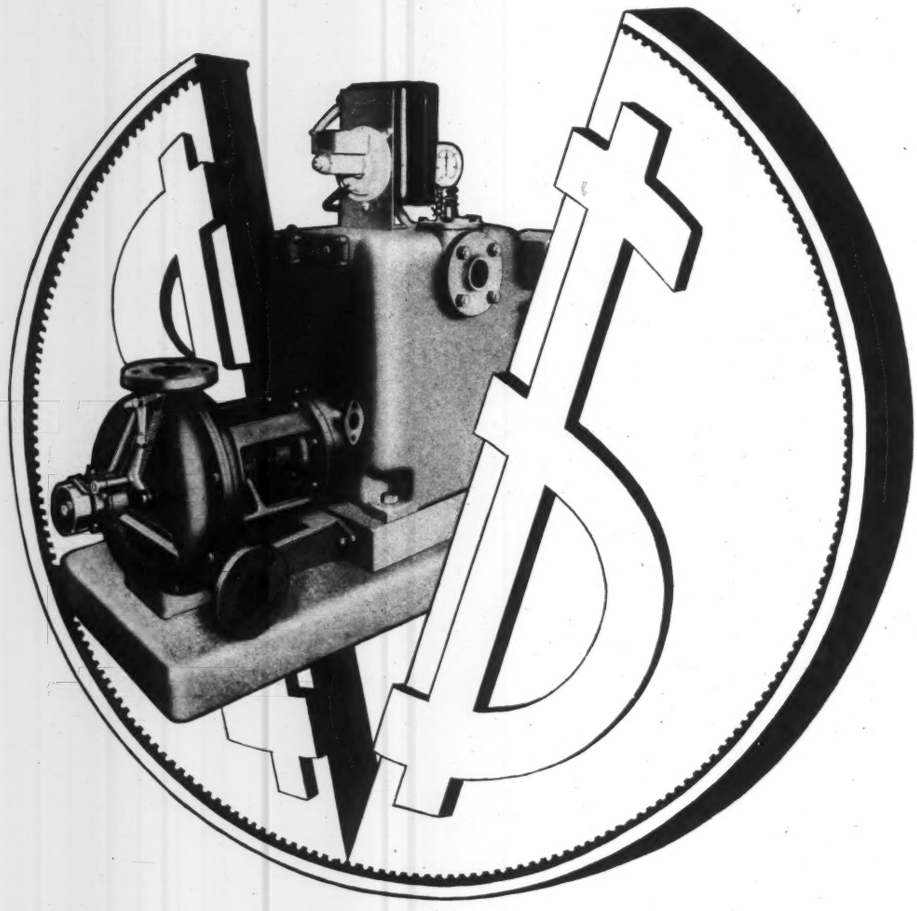

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Heating · Piping and Air Conditioning

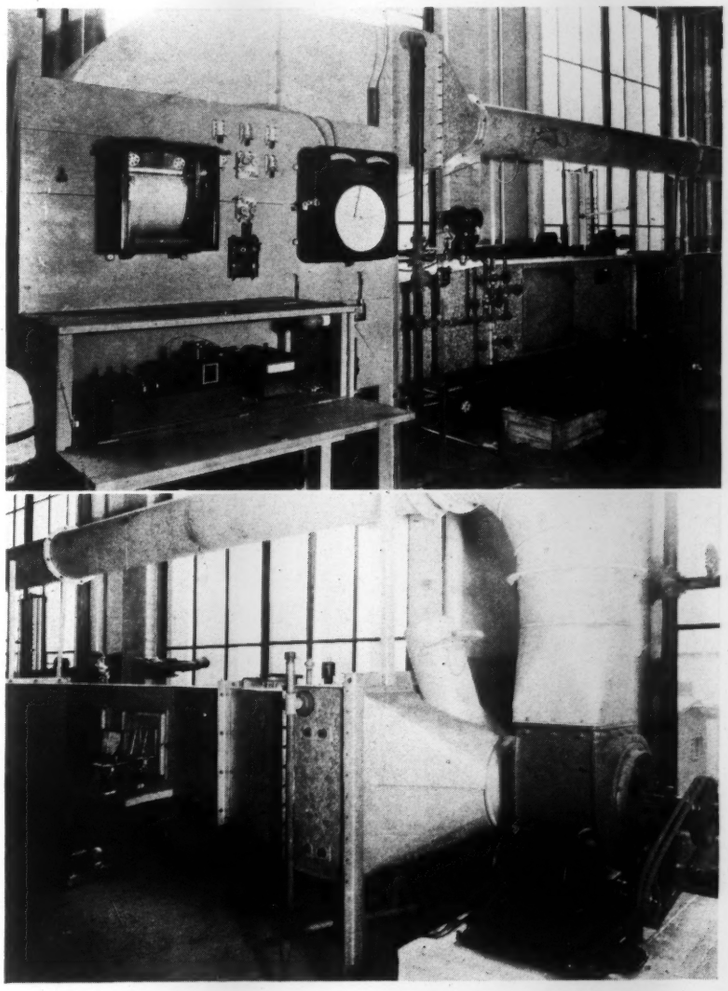
The Drying of Solids

A CLEAR understanding of industrial drying requires study not only of the engineering involved in the handling of proper air quantities for efficient moisture removal but also of the way moisture moves through solids, and how it vaporizes, in order that industrial drying equipment will not be wasteful of heat or space and drying may be accomplished efficiently. The department of chemical engineering at Massachusetts Institute of Technology has been working on a quantitative study[1, 2] of the drying of various solids, with particular reference to the way in which the moisture moves through the solid to its surface, whence it diffuses out

[1]Sherwood, *Ind. Eng. Chem.*, *21*, 12 (1929); *21*, 976 (1929); *22*, 132 (1930); *24*, 307 (1932); *25*, 311 (1933).
[2]Sherwood, *Paper Trade Jl.*, Feb. 21, (1929).

By T. K. Sherwood* and E. W. Comings†

Industrial Drying Research at M. I. T. Yields Data on Manner and Rate Moisture Moves Through Solids and the Effect on Dryer Operation and Design.



Above—Experimental dryer at M. I. T., showing instrument board with automatic temperature and humidity control, with recording balance between ducts at right. Below—Downstream end of dryer, showing high velocity section, enclosed cooling bank and blower

*Assistant Professor of Chemical Engineering, Massachusetts Institute of Technology, Cambridge, Mass.
†Assistant, Department of Chemical Engineering, M. I. T.

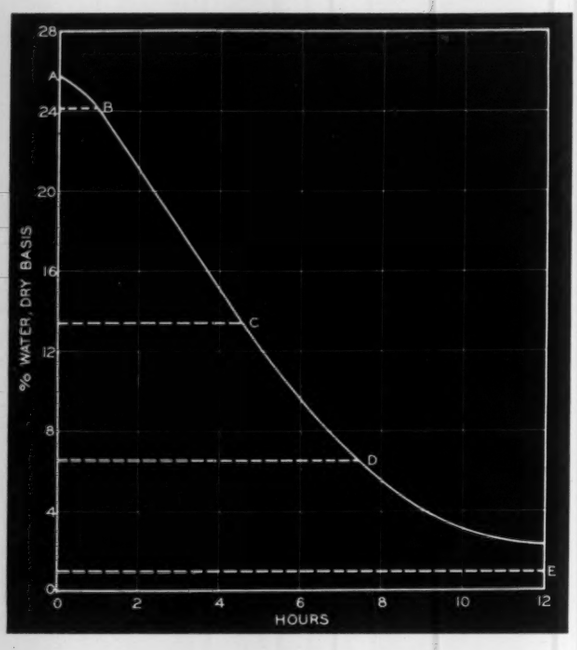


Fig. 1—Typical drying curve showing decrease of water content with time

into the air stream. Among the various materials whose drying characteristics have been studied in our laboratory are soap, starch, various types of clays, precipitated pigments such as whiting, wallboards, paper, pulp, several varieties of woods, and leather.

Before discussing the results of this industrial drying research let us review briefly the way in which solids dry.

The Way Solids Dry

The evaporation of water from the surface of a very wet solid is similar to the evaporation of water from an open pan exposed to air having less than 100 per cent relative humidity. The vapor pressure of water at the liquid surface is greater than the partial pressure of water vapor in the air, and the *water* tends to evaporate and diffuse as *water vapor* into the main air current. This diffusion is resisted by a layer of relatively stagnant air in contact with the water surface; this resistance is referred to as the resistance of the surface air film. High velocities of the air flowing past the liquid surface tend to reduce the effective thickness of this film and therefore to reduce the resistance to vapor diffusion. The rate of vaporization therefore increases with the air velocity.

If the water is initially at the same temperature as the air, the heat required for vaporization cannot at the start come from the air, but must be supplied by the water itself, which will cool. As the water temperature drops, heat is supplied at an increasing rate by heat transfer from the air, while at the same time the rate of vaporization decreases because of the reduced vapor pressure of the liquid. It is clear that an equilibrium temperature will be reached, at which point the heat required for vaporization will correspond exactly with the heat inflow from the air. It is also clear that the equilibrium temperature reached will be independent of the initial temperature of the water, and will depend only on the temperature and humidity of the air, and the presence or absence of means of heat supply other than by convection from the air across the wetted surface. In case the heat is received *solely by conduction through the same surface air film through which the vapor diffuses back into the air stream,* the equilibrium temperature reached is the *wet-bulb temperature* of the air. If heat is received by the solid being dried in other ways—such as by radiation from the surroundings—an equilibrium temperature will be reached, but this temperature will be higher than the wet-bulb temperature of the air. Thus, in actual drying operations, the wet solid may approach, but probably never reaches, the true wet-bulb temperature.

Initial Adjustment Period:

The wet solid entering a dryer is seldom at the equilibrium temperature, and must be exposed to the drying conditions for a short time before this temperature is reached. This first stage of the drying process may be termed the *initial adjustment* period. It is usually short, but in some cases, as in the drying of pulp lap, continues for as much as half the total drying time.

The Constant-Rate Period:

After the equilibrium temperature is reached, vaporization proceeds at a constant rate, provided the drying conditions are maintained constant. The "drying conditions" are the temperature, humidity, velocity, and direction of the air. This process of vaporization at a uniform rate at a constant equilibrium temperature frequently is the major part of the drying operation, and is termed the *constant-rate period.* The mechanism is that of vaporization from a free liquid surface, and drying proceeds as fast as vapor can diffuse through the surface air film. The rate of drying is greatly influenced by air velocity, temperature, and humidity, and, for insoluble solids, apparently does not depend on the nature of the solid. Although humidity of the air may change progressively and the rate of drying vary accordingly, this period is still referred to as the constant-rate period. Besides being influenced by the drying conditions referred to above, the rate is also influenced by any heat received by radiation from the surroundings, or by conduction through the solid from exposed dry faces.

The Critical Point and the Falling-Rate Period:

The rate of drying does not continue constant until the solid is dry, but at some definite moisture content of the solid the rate of drying begins to decrease, and continues to do so until the solid is dry. The point at the end of the constant-rate period at which the rate first starts to fall off is termed the *critical point.* The average moisture content of the solid at the critical point is termed the *critical moisture content,* and the range from there to dryness is termed the *falling-rate period.* The nature of the drying process changes at the critical point, and the critical moisture content is a very important quantity. It is primarily a function of the nature of the solid, but depends to a lesser degree on the way in which the drying is carried out. By experiment it has been found that the critical moisture content varies over

a wide range, being well over 100 per cent (dry basis) for certain wall-boards, and as low as 5 per cent for certain fine-grained non-hygroscopic solids.

Studying the Drying of a Solid

Data on the drying of a specific solid are conveniently analyzed graphically by an inspection of the plot of moisture content vs. time of drying. Fig. 1, based on data on the drying of a clay slab, is a typical example of such a plot. The intermediate linear section of the curve corresponds to the constant-rate period, and the initial adjustment period and falling-rate periods are also evident. However, the exact location of the critical point is not evident, and but little insight is gained as to the mechanism of drying by a study of such curves. If the slopes of this curve, *i.e.*, the rates of drying, are measured and plotted vs. the water content, as shown in Fig. 2, discontinuities appear which were not evident from Fig. 1. This second curve shows that the rate drops suddenly and not gradually at the critical point, and, in addition, discloses a second discontinuity in the rate curve near the middle of the falling-rate period. It will be apparent that in Fig. 2 drying starts at an initial moisture content indicated at *A*. The section *AB* of the curve is the initial adjustment period, *BC* represents the constant-rate period, and *CE* the falling-rate period. The analysis of rate-of-drying curves calculated from experimental data is a valuable method of attack in the study of the general mechanism of drying.

The rate curve in the falling-rate period *CE* may have any one of a number of shapes. The type of curve shown in Fig. 2 is typical, however, of the drying of many classes of solids. The section *CD* is frequently linear, usually having a positive intercept as shown at *F*. In this region *CD* water continues to evaporate at the solid surface, and although the rate of drying is decreasing, the mechanism is essentially similar to that during the constant-rate period. Consequently, in this first zone of the falling-rate period, the rate of drying is influenced by air velocity, air humidity, and other factors which influence the rate of drying from a free liquid surface. The decrease in the rate of drying immediately following the critical point is explained as being caused by a decrease in the total wetted surface, and the zone *CD* is termed the *zone of unsaturated surface drying*.

As the moisture content of the solid decreases, it becomes more and more difficult for the water to move through the porous structure of the solid. Eventually a moisture content is reached below which the rate of arrival of liquid at the solid surface becomes less than the rate at which the water *can* vaporize from the surface. The rate of moisture movement through the solid then becomes controlling, and a new group of factors becomes of importance as influencing the rate of drying. These are primarily the nature of the solid, its temperature, and its thickness.

The exact manner in which the moisture moves through the solid differs for the various materials, and in many cases is not well understood. However, the general term *diffusion* will be used in this connection, and it has been shown that this movement of moisture in many solids follows reasonably closely the fundamental

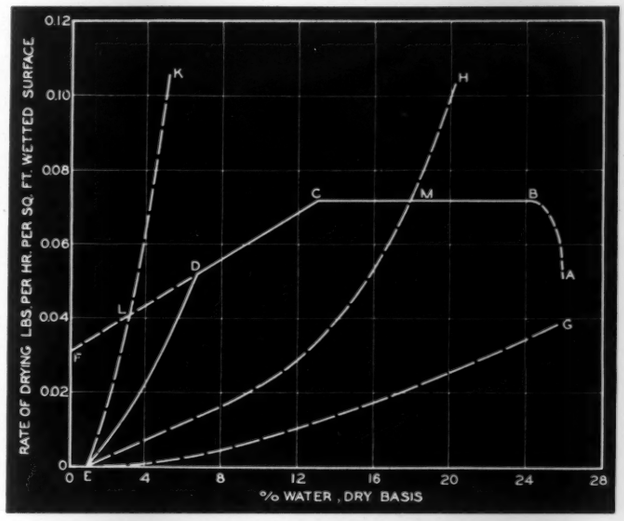


Fig. 2—Typical rate-of-drying curves. The solid curve, obtained by measuring the slopes of the drying curve of Fig. 1, shows discontinuities hardly perceptible in the original data

diffusion laws. The zone *DE* is therefore referred to as the zone where internal liquid diffusion is controlling. This is in distinction to the constant-rate period and the zone *CD*, where the mechanism is that of evaporation from a free liquid surface, and surface evaporation is said to be controlling. The "rate" of drying refers to the rate of loss of moisture as pounds per hour per square foot of exposed wet surface. With surface evaporation controlling, the rate in these units is essentially independent of the thickness of the solid, and, in the constant-rate period, is independent of the water content. With internal liquid diffusion controlling, the rate becomes dependent on both the thickness of the solid and its moisture content, *and practically independent of the air velocity and air humidity*.

The typical rate curve obtained with internal liquid diffusion controlling is concave upwards as in *DE* of Fig. 2. Since the rate of drying in this zone is dependent on the thickness and nature of the solid, changes in these variables will shift this section of the rate curve to *EK*, *EH* or *EG*. The rate of drying in the regions *ABC* and *CF* where surface evaporation controls will be unaffected by a change in thickness and probably to a minor extent only by the nature of the solid; consequently, the curve representing the final drying period will no longer intersect *ABCF* at *D*, but at *L* or *M*, or not intersect at all, as shown by *EG*.

Six General Types of Drying-Rate Curves

Depending on the location of this intersection, it follows that it is possible to have six general types of rate curves, as shown by the six curves of Fig. 3. Each of the three main possibilities is shown with and without a constant-rate period, since it is clear that the constant-rate period may or may not be obtained, depending on whether the initial moisture content is greater or less than the critical value. Curve *A* represents the rate curve for a solid which is so thin or so pervious to moisture that the region where internal liquid diffusion be-

comes the controlling factor is of negligible importance. For this to happen the intercept F of Fig. 2 will be negative. The initial moisture content is less than the critical and the whole process is essentially one of unsaturated surface drying. Such rate curves are frequently linear, as shown, but may be somewhat curved, usually concave downwards. Curve B represents the corresponding type where the initial moisture content is greater than the critical, and a constant-rate period appears. Curve D

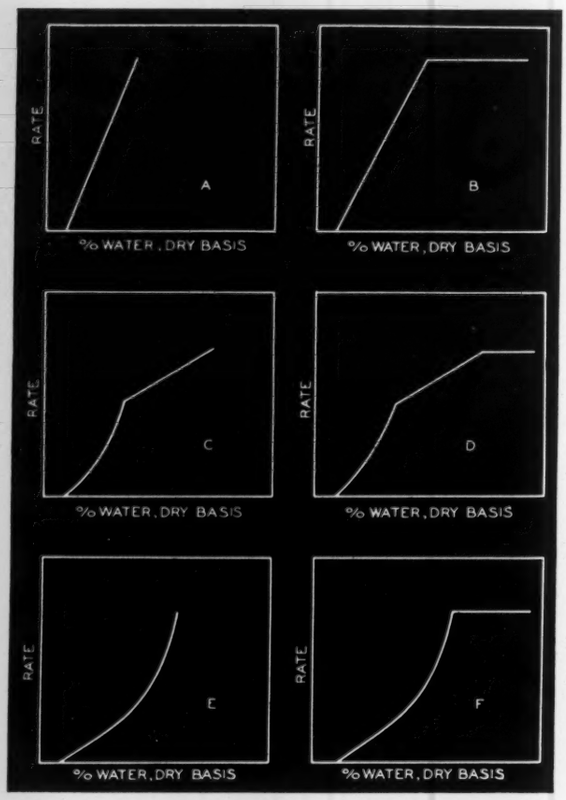


Fig. 3—Rate-of-drying curves obtainable in the air drying of common industrial materials

corresponds to the curve $BCDE$ of Fig. 2 discussed above. Curve C is of the same type without the constant-rate period. Curve E is of the type obtained with slow-drying materials where internal liquid diffusion is controlling from the start. Curve F is the corresponding curve with a constant-rate period, and is obtained when internal liquid diffusion becomes controlling at a moisture content greater than the critical point C of Fig. 2, where the rate starts to fall off because of a decrease in the wetted surface. From the discussion of Figs. 1 and 2, it should be clear that an initial adjustment period may precede the drying along any one of the six curves shown. These six curves of Fig. 3 are intended to be diagrammatic only, and should not be compared quantitatively. Furthermore, this discussion applies only to drying under constant drying conditions.

Equilibrium or Hygroscopic Moisture Content

Very few solids can be dried to "bone dryness" in contact with air containing any moisture, even if left for a very long time. As drying continues indefinitely the moisture content commonly approaches asymptotically[3] a definite "equilibrium" moisture content, as indicated at E on Fig. 1. Most dry solids placed in contact with air of a given humidity will pick up moisture until the same moisture content is reached as is approached in drying the solid at the same temperature and air humidity. For this reason, this equilibrium moisture content is called the "regain," and is of commercial importance in buying and selling hygroscopic materials such as textiles. Fig. 4 shows data on the equilibrium moisture relationships for three typical solids. Curve A is for the relatively non-hygroscopic kieselguhr, curve B for silk, and curve C for tobacco, which is very hygroscopic. Each curve consists of two branches, the first concave upwards and similar to typical adsorption curves; the second branches bend in the opposite direction, approaching the 100 per cent humidity ordinate as an asymptote. In wood technology, the moisture content at which the curve approaches closely the 100 per cent humidity line is termed the "fiber saturation point," but this value cannot be determined closely. Because of the general similarity between the "vapor pressure" curves of Fig. 4 and the rate curves of Fig. 3, it might be suspected that the falling-rate period is due to the reduced vapor pressures at

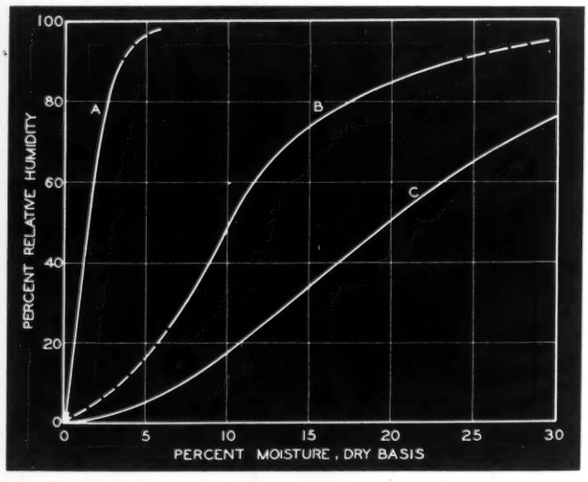


Fig. 4—Hygroscopic moisture or "regain" curves for typical solids. A—Kieselguhr. B—Silk. C—Tobacco

low moisture contents. This common conclusion is not correct, and, in general, there is no correlation between the critical moisture content and the fiber-saturation value.

Relation of Moisture Content to Drying Time

A study of the physical mechanism of the drying process is of practical value for two reasons: First, the mechanism of drying prevailing in the various stages of the drying process determines the factors influencing the rate of drying, and consequently a knowledge of the

(*To page* 68, *back Advertising Section*)

[3] *Asymptote:* A line that approaches nearer to some curve than any assignable distance but, though infinitely extended, would never meet it.—*Webster's Dictionary.*

Planning a Central Heating Plant *for a School or Institution*

Rarely is the engineer brought into the picture at the very inception of a group of institutional buildings. In nearly every case he is called upon to design a central heating plant for a group of buildings of various ages, often a complicated problem. In this article Mr. Kellogg describes, step by step, the working up of a complete program for heating a group of college buildings of different ages by steam supplied from a central plant

By . . . . . **Alfred Kellogg***

CUSTOM has arbitrarily decreed that the term *district heating* shall apply to the distribution of a heating medium, either steam, water or electricity, to portions of a municipality served usually by a public utility company, while the term *central plant heating* shall apply to a similar distribution for heating to a group of college or institutional buildings. This article is a description of certain engineering phases of design and installation peculiar to the latter—the central heating plant.

It is the purpose to describe in a general way, step by step, the working up of a complete program for the distribution of steam from a central heating plant for a group of college buildings, many years in educational service, each being supplied by its own means for heating. The engineering procedure in any case would be much the same, regardless of the size of the college or its location.

Buildings Are Usually of Various Ages

It is rarely that the engineer is brought into the picture at the very inception of an institutional group, and less rarely at the beginnings of a group of educational buildings. In nearly every case he is called upon to design a central heating—and possibly lighting—plant for a group of buildings of various ages. This is particularly the case with college buildings, many of which were built in the 19th century, and in the older parts of the country, some of them in the 18th century. He is thus faced at the outset with the problem of coordinating the several existing systems of building heating and consolidating them in some fashion to meet the requirements of a central plant.

He will, in most cases, find in some of the older buildings an installation of warm-air furnaces; in other buildings one-pipe steam jobs; in still others, two-pipe installations; yet again, a gravity hot-water system of heating; and possibly also, in some of the more recently erected buildings, one or more of the present-day vapor or vacuum systems of heating.

In nearly all of the installations, warm-air furnaces and boilers will be found in the basements, with an occasional instance of one or two boilers serving two or more buildings that chance has placed near one another.

Now as it is safe to assume that the engineer has a restricted appropriation to work with, he must first determine just how many of the building heating installations he must scrap; how many he can salvage and adapt to any modern system of central-plant heating, and along with this must be considered the economic advantages to be expected from the distribution of steam from a single plant as against the operation of many small boilers with the attendant fire risk, particularly in the older second class buildings; also the removal of ashes from each plant, and the nuisance and expense inevitably caused thereby.

The saving in labor many times has a bearing on the final result, which must not be neglected in the calculations.

The distribution of steam to the group of buildings under consideration was mentioned above. Of course, hot water in some cases might serve better, but in a group of buildings with such a heterogeneous assortment of heating services to be coordinated—and such are not at all unusual—it will usually be found that the altered building installations to be retained can better be adapted to a central steam supply than to hot-water circulation.

The buildings that were heated from warm-air furnaces will likely be equipped with a two-pipe vapor installation, and possibly with some form of zone control.

The one-pipe steam jobs, if retained on the score of installation cost, may be supplied with vacuum air valves, the returns trapped to the underground vacuum return mains, and the vacuum air line carried to the same main outside the building return trap. If, on the other hand, a gravity return to the boiler plant is decided upon, radiator air valves of the usual pattern will meet the situation, but the circulation through the system will be slower.

The old two-pipe work may be changed by the removal of the air valves and fitting the radiators with

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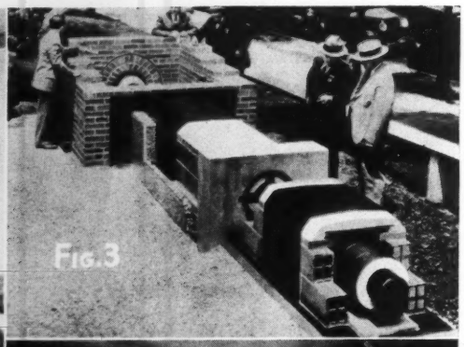
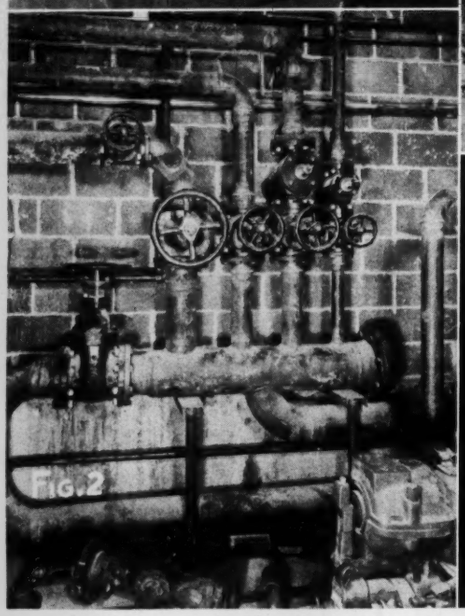




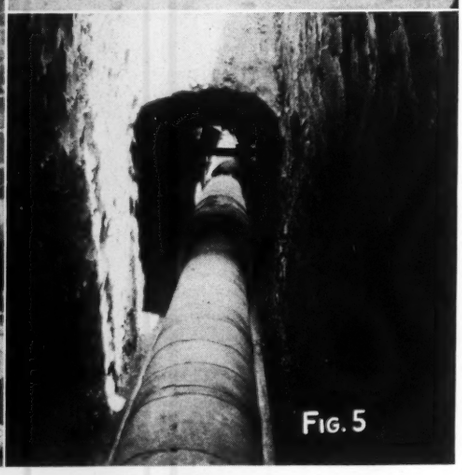


Fig. 1—Arrangement of piping in a tunnel. Fig. 2—Manifold piping in pump room at a prominent Eastern college. Fig. 3—A type of built-up conduit with two tile underdrains laid in crushed stone under a concrete base. Fig. 4—End view of another form of built-up conduit. Fig. 5—A similar installation

thermostatic traps, and the present or new building returns would be carried to the new underground mains.

The vapor systems, where such occur, may be readily adapted to the new central plant supply and return, and the old buildings heated by hot water may be changed by the substitution of a hot-water tank for the coal-burning water-heating boiler, and the gravity flow and return piping connected to the tank. The tank would be heated by central-plant steam through suitable coils therein, or through an indirect water heater, either arrangement being placed under thermostatic control.

In some colleges, hot water is required for the use of the janitors during the summer vacation period. In others, such is not the case. This service may be supplied to the buildings by water heated at the central plant and forced circulation, or the storage tanks in the individual buildings may be heated through an indirect steam heater, with steam supplied from the central plant.

Either scheme will serve to remove all fire risks due to the heating system.

Locating the Boiler Plant

After determining the present load, with ample allowance for future buildings and their probable location on the college property, the selection of a suitable location for the central plant is in order. This will be determined not necessarily from a strictly engineering viewpoint, but also after due consideration has been given to the final appearance of the grounds, proximity to other college buildings and to the property of other owners. If the services of a landscape architect have been secured, cooperation with him will be desirable, and frequently will obviate costly changes later.

Choosing the Type of Boilers

The central plant location having been decided upon, the selection of the type and size of the boilers and auxiliaries should be taken up.

In the small plant, steel boilers of the brick-set return-tubular or portable return-tubular type will satisfactorily meet requirements. They are simple in design and construction. The portable style is encased in steel and the setting thus is made practically air tight and affords increased efficiency.

The all brick-set boiler may be made equally efficient with a steel jacket, but the installation cost is somewhat increased.

In the larger plants, consideration should be given to the selection of one of the several types of water-tube boilers on the market.

The character of the water supply available will have a bearing on the final choice, and especially is this of importance if much make-up feed water is likely to be required.

If one of the various types of water softeners available is deemed necessary in any event, then the type of water-tube boiler is of less importance and the final selection will be governed by other considerations.

The load on a central heating plant varies widely over the 24-hour period, although the fluctuations are not rapid. This must be taken into account in the design of the plant, and one or more spare units are needed to meet the usual operating conditions. This applies also to the more important plant auxiliaries, such as boiler-feed pumps, stoker fans, etc.

Selecting the Fuel

The type of fuel to be burned will be governed largely from its cost in the particular locality and from the reliability of the supply. Also, the neighborhood must be considered, having in mind the possibility of some time creating a smoke nuisance. Frequently, smoke ordinances will be the determining factor of the fuel selected.

If coal is to be the fuel, mechanical stokers will in nearly every case prove a wise investment. Overfeed stokers of either the hand or mechanical type are suitable for use in the smaller plants where the volatile content of the fuel does not exceed 22 per cent and the fusibility of the ash is above 2350 F.

Where high-volatile or low-fusing ash coals are to be burned, the underfeed stoker with forced draft will afford satisfaction.

Setting heights also will be determined by the character of the fuel and local ordinances. Good practice will limit the thermal release from the fuel to 20,000 Btu per cu ft of combustion space under average loads, with a maximum release of 35,000 Btu at extreme boiler output. Authorities are not fully in accord on this point, but the volumes stated will prove satisfactory, both in regard to the possibility of objectionable smoke at the higher ratings, and equally so in the less frequent need of furnace repairs and upkeep.

Coal- and ash-handling equipment will usually prove a paying investment in plants of 1,000 hp and larger.

Oil makes a very satisfactory fuel, as it affords freedom from dust and smoke, and in all cases the closing of a valve eliminates standby expense for the time being. Natural gas offers similar advantages, and in some parts of the country may compare favorably in cost with other fuels.

Generate or Purchase Electricity?

Whether electricity for light and power needs should be purchased or generated on the premises, must be given careful consideration in both the design and arrangement of the central plant, and equally so in the design of the underground system of steam distribution to the buildings.

The smaller college will more frequently close all its buildings during the summer months, in which case the central plant will usually be found deserted, and where low rates for purchased current can be secured, it will usually be found unprofitable to make the needed investment in electrical equipment.

In the large institutions, and where summer schools are regularly a part of the educational service rendered, the central plant is likely to function during the spring and fall months for supplying steam to dormitories, for domestic hot-water service, and for kitchen and dining room needs. These are matters requiring careful consideration before deciding the matter of purchased or manufactured electricity.

The larger installations may with economy install their own electric plant and provide auxiliary outside electric connections for added security, and for limiting investment in standby equipment.

No fixed rule will apply for providing this needed utility.

Piping the Steam

The underground supply of steam from a central plant requires perhaps as great if not greater skill in design and installation as any other feature of the plant.

Many factors determine whether the distributing pip-

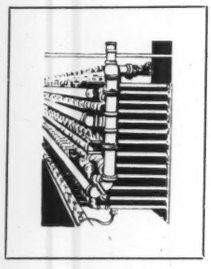
(*To page 75, back Advertising Section*)

Fig. 6—This view gives a good idea of the difficulties to be overcome in laying distribution piping in city streets

How to Save by

Modernizing Refrigeration Piping

PIPING, used in large quantities in every industrial refrigeration plant regardless of the plant's prime purpose, represents a considerable item in initial capital investment cost as well as in operation and maintenance; it must be carefully used in order that maximum performance may be obtained. If too much piping is used in any part of the plant equpiment, the money is squandered. If too little piping is used, operation suffers through lack of balance in capacity or excessive operating costs. In the case of too much piping, an excessive investment is made where less pipe might be used for the purpose but the extra money is spent just once. In the case of too little piping, the diminution in capacity or excessive operating cost necessary to obtain satisfactory, even if not maximum capacity, production is a constant loss or expenditure and often represents the cost of piping originally omitted many times over. Hence the saying "Plants pay for piping, whether they have it or not."



Check-Up of Piping Will Pay

Piping represents such a large part of every refrigeration plant that it deserves intelligent treatment. Modern plants are constructed in the light of recent developments in the art by architects and engineers well versed in this profession. Old plants were often constructed from more or less hastily prepared plans—if any—with little thought given to the engineering possibilities of piping. Sometimes inferior substitutions were made and the piping and equipment were skimped to barest necessities.

Plants so constructed that have not yet modernized their old equipment still have it on their program—whether listed or not—for the principle of "survival of the fittest" holds true. A check-up of every plant, no matter when constructed, is advisable.

Two Classes of Refrigeration Piping

Piping used in refrigeration plants may be roughly grouped in

1. Piping to form surface, and
2. Piping to act as conduit.

In the first class, pipe is used as so much heat-transfer surface in order to collect heat from the material to be refrigerated and pass it through the pipe wall to the refrigerant within the pipe. The material to be refrigerated may be solid, fluid, viscous or thin, high- or low-gravity liquid, gas, vapor or air of various specific heats, or what have you. The refrigerant may be water, brine, or some volatile refrigerant. Yet, whatever the application, the factors affecting its performance are quite well known and in a new plant may be properly calculated. In an existing plant the piping may be checked to determine how it compares with current piping practice and changes made to make it conform if desirable.

After the heat has been absorbed by the refrigerant, it must be conducted from one piece of equipment to another and finally eliminated from the plant in the condenser water. Most refrigerating fluids must be conserved and recirculated, which demands a definite cycle in closed piping; this piping acts simply as so much conduit to conduct the fluids from one piece of apparatus to another in the operating cycle.

Match Pipe Surface to Load

Amount of pipe surface required for a given tonnage must be carefully matched with the load; the conditions will determine the performance factors to be used. If the problem at hand be one of cooling a cold-storage room with either brine or direct-expansion ammonia, the rates of heat transfer will vary with wetted surface, defrosting, etc., but in general, with the customary heat insulants used, the surface may be determined by reference to the charts shown in Figs. 1 and 2.

Example: What amount of 2 in. brine pipe should be used in a cold-storage cooler measuring 30 ft by 80 ft by 11 ft to maintain 33 F?

Volume = $30 \times 80 \times 11 = 26{,}400$ cu ft

Fig. 1 shows ratio 14:1

Pipe = $26400/14 = 1886$ lineal ft of 2 in.

Example: What would the same condition require for direct expansion ammonia?

Fig. 2 shows ratio 22:1

Pipe = $26400/22 = 1200$ lineal ft of 2 in.

In case it is desired to use 1¼-in. pipe, multiply the 2 in. ratio by 0.70 to determine equivalent amount of pipe surface.

Allow for All Heat Items

If the process load is very active, due allowance must be made for all items of heat by making a heat balance and computing load on an hourly rate in order to calculate sufficient pipe to match the load. Otherwise the surface will be deficient and it will be necessary for the

plant to operate with a larger temperature head or difference than is economical, to produce capacity results.

In any case, the surface may be readily calculated from the formula:

By R. C. Doremus*

who tells how to rehabilitate refrigeration piping to prevent excessive operating cost and loss of capacity . . . . . .

$$H = A \times U \times (T_1 - T_2)$$

where

H = Total Btu load per hour
A = Area of transfer surface
U = Heat transfer factor
T_1 = Temperature of material to be cooled
T_2 = Temperature of refrigerant

provided the U value of the surface is known or can be determined.

Several Room Temperatures With One Refrigerant Temperature

There are numerous cases where rooms of various temperatures are to be controlled on one refrigerant temperature, which means variations from standard conditions in temperature head. If one case uses a 15-F head, it will require twice as much surface as one using a 30-F head. Or, conversely, a system may be operating at large temperature heads, whereas with a little revamping and the addition of some surface to a weak point it may be able to handle the load with a smaller temperature head. This means that the compressor can do its work at a higher back pressure at a temperature nearer the plane of the load; such operation is more efficient in that the compressor handles a larger tonnage at higher back pressure and hence can handle the load in less time at a saving in power—which is a saving in operating cost.

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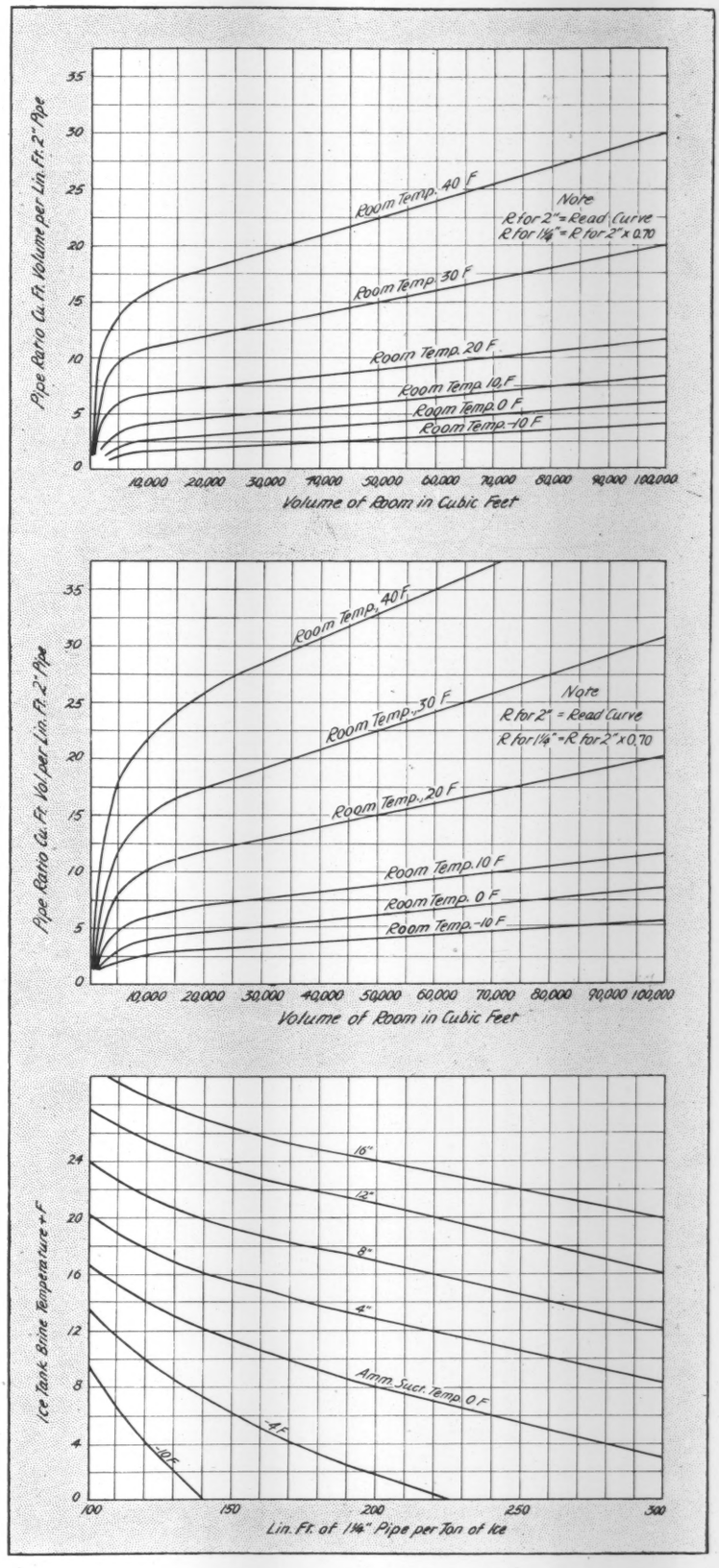

Pipe Ratio Cu. Ft. Volume per Lin. Ft. 2" Pipe
Room Temp. 40 F
Note
R for 2" = Read Curve
R for 1¼" = R for 2" x 0.70
Room Temp. 30 F
Room Temp. 20 F
Room Temp. 10 F
Room Temp. 0 F
Room Temp. -10 F
Volume of Room in Cubic Feet
Pipe Ratio Cu. Ft. Vol. per Lin. Ft. 2" Pipe
Room Temp., 40 F.
Room Temp., 30 F.
Room Temp., 20 F.
Room Temp. 10 F
Room Temp. 0 F.
Room Temp. -10 F.
Note
R for 2" = Read Curve
R for 1¼" = R for 2" x 0.70
Volume of Room in Cubic Feet
Ice Tank Brine Temperature ÷ F
16"
12"
8"
4"
Amm. Succ. Temp. 0 F
-4 F.
-10 F.
Lin. Ft. of 1¼" Pipe per Ton of Ice

Fig. 1 (top)—Pipe ratios in cubic feet volume per lineal foot of 2-in. pipe for maintaining various temperatures in well-insulated rooms by a brine system

Fig. 2 (center)—Pipe ratios in cubic feet volume per lineal foot of 2-in. pipe for maintaining various temperatures in well-insulated rooms by direct-expansion system

Fig. 3 (bottom)—Lineal feet of 1¼-in. pipe per ton of ice

Table 1—Square Feet of Direct-Expansion Pipe-Coil Surface in Air Per Ton of Refrigeration Per Day

Suction Temp F	Room Temperatures						
	—10	0	10	20	30	40	50
30	.....	.....	.....	.....	.....	480	240
25	.....	.....	.....	.....	960	320	192
20	.....	.....	.....	.....	480	240	160
15	.....	.....	.....	960	320	192	137
10	.....	.....	.....	480	240	160	120
5	.....	.....	960	320	192	137	107
0	.....	.....	480	240	160	120	96
− 5	.....	960	320	192	137	107	88
−10	.....	480	240	160	120	96	80
−15	960	320	192	137	107	88	74
−20	480	240	160	120	96	80	69
−25	320	192	137	107	88	74	64

The above table is calculated using $K = 2.5$ Btu/sq ft/F diff./hr
For lineal ft of 2-in. pipe, multiply tabulated value by 1.61
For lineal ft of 1¼-in. pipe, multiply tabulated value by 2.30

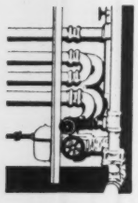


Table 2—Square Feet of Brine Pipe Coil Surface in Air Per Ton of Refrigeration Per Day

Brine Temp F	Room Temperatures						
	—10	0	10	20	30	40	50
30	.....	.....	.....	.....	.....	343	172
25	.....	.....	.....	.....	685	229	137
20	.....	.....	.....	.....	343	172	114
15	.....	.....	.....	685	229	137	98
10	.....	.....	.....	343	172	114	86
5	.....	.....	685	229	137	98	76
0	.....	.....	343	172	114	86	69
− 5	.....	685	229	137	98	76	62
−10	.....	343	172	114	86	69	57
−15	685	229	137	98	76	62	53
−20	343	172	114	86	69	57	49

The above table is calculated using $K = 3.5$
For lineal ft of 2-in. pipe, multiply tabulated value by 1.61
For lineal ft of 1¼-in. pipe, multiply tabulated value by 2.30

Table 1 indicates the amount of direct-expansion pipe-coil surface in square feet per ton of refrigeration per day in the case of cooling gravity-circulated air, based on a U factor of 2.5 Btu per sq ft per hr per degree F of temperature head.

Example: What pipe surface is required to handle a 4-ton load at 10 F in one room and a 5-ton load in a second room at 30 F, with a suction temperature of — 5 F on an ammonia direct-expansion system?

First room (From Table 1)

$A = 4 \times 320 = 1280$ sq ft $= 1280 \times 1.61 = 2050$ lineal ft of 2-in. pipe

Second room (From Table 1)

$A = 5 \times 137 = 685$ sq ft $= 685 \times 1.61 = 1100$ lineal ft of 2-in. pipe

Note: For any given condition, it is obvious that a larger amount of surface will permit the same tonnage to be operated at a higher suction pressure and temperature or a lower temperature head inasmuch as:

$$H = A \times U \times (T_1 \times T_2)$$

which is the fundamental heat transfer formula.

Similarly, Table 2 indicates the amount of brine pipe coil surface required in square feet per ton of refrigeration per day based on a U factor of 3.5 Btu per hr per sq ft per degree F of temperature head.

Example: What pipe surface is required to handle a 4-ton load in one room at 0 F and a 4-ton load in another room at 30 F with —10 F average brine temperature?

The brine supply may be —12.5 F and the return brine may be —7.5 F with an average in the coil of —10 F

First room (From Table 2)

$A = 4 \times 343 = 1372$ sq ft $= 1372 \times 1.61 = 2212$ lineal ft of 2-in. pipe

Second room (From Table 2)

$A = 4 \times 86 = 334$ sq ft $= 334 \times 1.61 = 538$ lineal ft of 2-in. pipe

Length of Piping per Coil

In any pipe coil surface, the refrigerant itself has a very definite heat-absorbing capacity, and therefore consideration must be given the length of piping used per coil. In the direct-expansion system, if too much length is used on one feed or expansion valve, the vapor velocities are excessive if saturated, or if not saturated the vapor becomes greatly superheated. Inasmuch as 2-in. pipe and smaller is generally used for this purpose, it is considered satisfactory to use a 2,000-fpm maximum vapor velocity at the suction end of the coil or an average velocity throughout the coil of 1,000 feet per minute. Table 3 indicates maximum lengths for one continuous coil of direct-expansion ammonia piping based on a 1,000-fpm average vapor velocity.

Normally, deviations may be made from Table 3 at the expense of wire-drawing and pressure drop from high vapor velocities. The values given are indicated as good practice from practical experience and are used as criteria from a design standpoint.

The maximum length of one continuous coil of brine pipe is likewise a question of heat transmission rate. This is reflected by the rise in brine temperatures as it passes through the pipe coil. It is customary to use ¾-in. or 1-in. control valves with coils of either 1¼-in. or 2-in. piping with a brine velocity through the coil of approximately 0.75 feet per second, or 45-fpm. The specific heat of the brine will vary with temperature and gravity but throughout the cycle these are fairly constant. Therefore, it is considered economical to permit a 5-F rise through the coil and from 1- to 2-F further rise in the mains according to the size of the system

Under such conditions, there are maximum areas of pipe surface that should be used per valve to limit the brine temperature rise to 5-F. Table 4 is a tabulation of such lengths.

Too-Long Piping Wasteful

Longer lengths mean either a larger brine temperature rise than 5-F (consequently a lower back pressure for the compressors) or a higher brine velocity through coils, which means higher pumping costs. Conversely, the use of the Table 4 values or smaller means a brine temperature rise less than 5-F (or that less brine will be required if the rise is maintained at 5-F); this spells less pumping cost. It permits flexibility in pumping; two brine pumps of, say, 400 gpm and 200 gpm may be used in a cold-storage plant to meet varying loads.

In ice-manufacturing plants, direct-expansion ammonia piping is submerged in sodium or calcium brine. Fig. 3 shows the lineal feet of 1¼-in. extra-heavy pipe used per ton of ice with a gravity feed system based on a U of 30 Btu per hr per sq ft per degree of temperature head.

Scant Pipe Surface Costs Money

Thus it is plain that if a pipe surface is scant for a certain job it can be and is compelled to handle the load by giving it a larger temperature head. This means lower back pressure at which the compressor must operate. Inasmuch as ammonia or any other commonly-used volatile refrigerant inherently has a larger specific volume of vapor at lower back pressures than at high back pressures, it means that more compressor displacement will be required to handle a given tonnage capacity. The plant *may* have excess compressor capacity but *usually* it has not, which means it must be supplied. In any event, it means operating more compressor capacity than would otherwise be required. If the compressors are running only part time due to excess compressor capacity, it means they must run longer to accomplish the same tonnage; if they are already running 24 hours a day, another compressor must be installed. It is foolish economy to skimp on pipe to save initial capital investment and pay for this omission forever in additional compressor equipment and power bills. We must not send a boy to do a man's job.

From a practical standpoint, no plant—new or old, modern or antiquated—should be operated at an abnormally large temperature head. If it is a modern plant, no doubt it will meet specifications of a definite duty for a certain schedule. If it is antiquated, time may have played peculiar antics in changing the schedule and the nature of the service, or in wear or obsolescence requiring revamping of piping and equipment. However, the mere requirement does not compel action. Some plants see the light and make changes to obtain operating economies. Others know changes should be made but hesitate to make them. Still others do not see the necessity and may not know of it. They will continue to operate at a disadvantage in ignorant bliss until forced to shut down.

Note: A later article will consider main piping, fluid velocities and friction drops.

Table 3—Maximum Length in Feet of One Continuous Coil of Ammonia Direct Expansion Room Piping

Based on average vapor velocity of 1,000 fpm

Pipe Size In.	−27 F 1 Lb	−20 F 4 Lb	−15 F 6 Lb	−10 F 9 Lb	−5 F 13 Lb	0 F 16 Lb	+5 F 20 Lb	+10 F 24 Lb	+15 F 28 Lb	+20 F 33 Lb	+25 F 39 Lb	+30 F 45 Lb
½	216	268	285	335	382	435	485	543	602	675	758	842
¾	318	393	420	493	563	641	718	800	885	991	1115	1240
1	425	525	562	660	757	853	960	1070	1180	1325	1490	1660
1¼	600	742	795	932	1070	1215	1360	1510	1670	1870	2110	2340
1½	732	900	960	1135	1300	1470	1650	1840	2040	2290	2570	2850
2	973	1200	1285	1510	1725	1960	2200	2450	2720	3030	3410	3800

A = Internal area of pipe in sq in.
Vmax = Maximum velocity of vapor in coil inches per min.
E = Refrigerating effect in Btu per cu ft
Ta = Temp. difference inside and outside of coil in F
Smax = Maximum surface of coil in sq ft
K = Constant representing safety factor = 0.75

$$S\text{max} = \left[\frac{E\ (A \times V\text{max})}{1728}\right] \times \frac{60}{4 \times 10^{\circ}} \times K = \left[\frac{E\ (A \times V\text{max})}{1728}\right] \times 1.13$$

Table 4—Maximum Area of Indirect Brine Coil Surface Per Valve to Maintain 5-F Rise with Average Brine Velocity of 0.75 fps

Brine Temp F	Room Temperatures −20	−15	−10	−5	0	5	10	15	20	25	30	35	40	45	50
30	...	...	...	...	...	...	...	...	...	...	...	870	435	290	218
25	...	...	...	...	...	...	...	...	...	...	870	435	290	218	174
20	...	...	...	...	...	...	...	...	...	870	435	290	218	174	145
15	...	...	...	...	...	...	...	...	870	435	290	218	174	145	124
10	...	...	...	...	...	...	...	870	435	290	218	174	145	124	109
5	...	...	...	...	...	...	870	435	290	218	174	145	124	109	97
0	...	...	...	...	...	870	435	290	218	174	145	124	109	97	87
− 5	...	...	...	...	870	435	290	218	174	145	124	109	97	87	79
−10	...	...	...	870	435	290	218	174	145	124	109	97	87	79	73
−15	...	...	870	435	290	218	174	145	124	109	97	87	79	73	67
−20	...	870	435	290	218	174	145	124	109	97	87	79	73	67	62
−25	870	435	290	218	174	145	124	109	97	87	79	73	67	62	58
−30	435	290	218	174	145	124	109	97	87	79	73	67	62	58	55

The above table is based on: K = 3.50 Btu/sq ft/F diff./hr

On practically every air-conditioning and ventilating job noise must be considered as a factor in the design. Sound isolation of mechanical equipment is important and must not be overlooked. Prevention of air noise must be arranged for by selection of the right fan and correct design of the duct system.

In this article the author describes methods he has used successfully in a number of cases for preventing transmission of noise from the machinery room. He also discusses the use of air-cleaning devices as noise bafflers, presenting the results of an investigation made on an air-filter installation in a radio broadcasting studio

By **Samuel R. Lewis***

Noise in Heating and Air Conditioning

Where It Occurs; How It's Prevented

IMPORTANT in air conditioning is noise prevention. Preventing the transmission of objectionable sound from mechanical apparatus is fairly well understood, though in several noteworthy instances provisions for doing this have been neglected in the original design. In such cases, while the fault can be corrected later, such correction is embarrassing and usually will be found to cost more than would have prevention.

Fan and Motor Should Be Isolated

The fan and its motor, whether direct-connected or belted, should both be fastened securely to the same rigid foundation. This foundation must be isolated from resonant contact with the building structure or with anything which is in resonant contact with the building structure. Such isolation of the machinery foundation has been accomplished successfully with pads of cork, rubber, felt, and with spiral springs. It is important, considering endurance, that organic materials such as cork, rubber and felt be kept oil- and water-free; otherwise their useful life will be shortened unduly.

I know of one important bank building in which the fans were bolted to a laminated wood base which in turn was floated on cork, with cork-covered edges bearing against heavy bolted-down restraining curbs. The plant operated satisfactorily and was accepted. The operating engineer, seeing the cork-filled crack between the wood base and the curb, concluded that some one had been careless about finishing things up, and painstakingly wedged hardwood filler strips in place so as to cover up the cork. Immediately an unprecedented and unbearable noise was observed in the banking room, and it required an inspection trip by the designer of the plant before the trouble could be located and remedied.

Treat Machinery Room with Noise Absorbent

There are other noises in machinery rooms such as induction-whine with electric motors, belt friction noises, etc., which floating foundations will not always eliminate. It is wise, therefore, to treat the walls and ceilings of these rooms with noise-absorbing material. This may be perforated-metal-covered hair felt or cellular blocks such as are used for ceilings in finished rooms, or may be fireproofed fibers covered with coarse wire screen. The fire insurance underwriters object to the use of canvas or muslin as a finish for sound proofing walls and ceilings of machinery rooms.

Provides Grillage of Beams to Carry Piping

In one modern, fireproof monumental church building the boiler room is under the parish house. The floor slab over the boiler room is of concrete from which is suspended a great many heavy pipes, ducts, etc. The people in the parish house can hear every occurrence in the boiler room; each cycle of operation of the stokers; every time the fireman grounds his shovel or lays down his slice bar; every time he opens a water faucet to take a drink or to wash his hands.

To insulate the ceiling of this boiler room against

*Consulting Engineer, Chicago. Member of Board of Consulting and Contributing Editors.

sound transmission at this late date is well nigh impossible, since the maze of hangers and the interlaced and obstructing pipes and ducts offer insurmountable interference. All of these hangers also transmit heat to the concrete slab and the reaction to the whole construction is most unfavorable.

I happen to have evaded such a situation as that just described on several recent occasions. The boiler-room and engine-room ceilings would be called upon to support the pipes and ducts of many different contractors, and if nothing was done about it the ceiling could be punched full of holes and the fireproofing of the beams would be knocked off and a disgraceful mess in general would result.

We therefore designed the ceiling slab as a ceiling slab, fireproofed and heat-proofed it, and left a little chance for eventual installation of soundproofing if this should be necessary. Below this slab and entirely independent of it, we provided a grillage of comparatively inexpensive non-fireproofed steel beams, designed solely to carry the pipes and the ducts for all interested contractors. Savings in labor and interference easily paid the cost, and the concrete slabs of the building were kept free of hanger holes.

Air Flow May Cause Noise

There is another type of noise in ventilating systems due to the rushing and roaring of the air itself through the fan blades and against the housings and around the elbows. One may stand beside the fan and not hear any unusual sound, but if he enters the discharge duct he will find it difficult to believe that something has not broken loose in the brief interval since he stood outside. The apparent answer is that the engineer who selected that particular fan was guilty of bad judgment. He should have used a larger, slower fan, and larger, "slower" ducts.

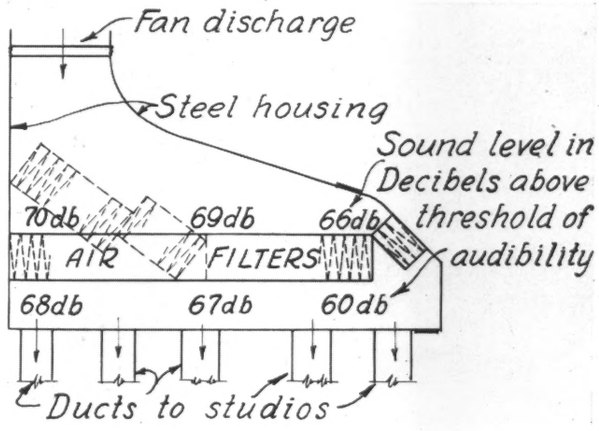


Fig. 1—Sketch of air-filter installation at a radio broadcasting studio. Note the trifling sound reduction when the noise impinges at right angles to the filter structure and the considerable reduction, due to angularity of impact, between the locations marked "70 *db*" and "60*db*." The dotted lines indicate a probable improvement in filter arrangement from the standpoint of noise reduction

However, perhaps the particular fan and the particular ducts were justified for other good reasons. In any event they are in place and what are we going to do about it?

I have been studying this matter off and on during the past year.

Claim is made for several air-cleaning devices that these, if placed on the discharge side of the supply fan, will reduce the air-rushing noise. I have never seen a ventilating system in which the air filters could reasonably be placed on the discharge side of the supply fan except where the whole design of the apparatus room was predicated on such an arrangement. I am sure that in very few cases could already-installed air filters be changed from the inlet to the outlet of the supply fan without serious and costly reconstruction.

Reducing Air Noise with Baffles

Noise from rushing air can be reduced materially by porous or fibrous narrow baffles placed successively at an angle across the air-way, and the volume of air need not be too badly reduced thereby. We have absorbed in this manner about one-third of the noise with a pressure drop of less than 0.25 in. The noise, traveling faster than the air, goes straight ahead and tends to be absorbed by the baffles even though they are at an angle, while the air bends itself around between the baffles. If the narrow baffles are staggered across the air-way at right angles to the air direction they are more effective as sound-sponges than if staggered at an angle, but are also too effective in stopping air flow.

We found that metallic air-filter cells of the viscous-coated type were of little value in air-noise absorption when placed on the discharge side of a supply fan at ordinary ventilating system speeds such as correspond to 0.75 in. total resistance.

We found that zigzag fabric air filters were of no more benefit than the metallic type except when these were placed at an angle to the direction of air flow. When so placed, giving many thicknesses of fabric successively to the high-speed sound waves, there was a reduction of 15 per cent in noise due to the filters, and there was no noticeable increase in resistance to air flow.

Filter Installation Tested

These results were so interesting that we tested an actual installation in a radio-studio where a throw-away type of air filter is installed on the discharge side of the supply fan. This type of air-cleaning device uses a paper-like fabric in large zigzag sheets. The results of our observations are shown in Fig. 1.

Where the noise impinges at right angles to the filter structure the reduction in air noise due to the filter was 2 decibels; negligible ordinarily. Where the air and the noise met a large number of the angularly-arranged sheets of fabric at an angle, however, there was a 10-decibel reduction, quite worthwhile. This field observation seems to prove our laboratory hypothesis and to indicate that for similar future cases where the air-cleaning devices are placed on the discharge side of the fan, it would be wise to arrange them in gangs always at an angle to the direction of main air flow, as suggested by the dotted lines superimposed on Fig. 1.

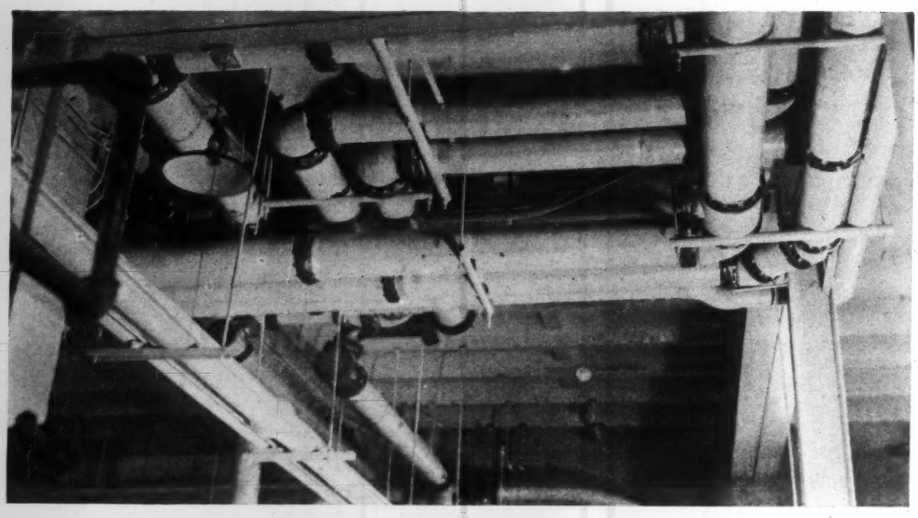


Fig. 1—The mains leading from the boiler header to the many points of use of steam in the Atlas brewery. In addition to its process uses, these mains furnish steam to a uniflow engine, water pumps, air compressors, the refrigerating compressors, bottling department, etc. The change in direction of the lines was made to eliminate expansion trouble

Piping Services in a Brewery

. . . . . include piping for high-pressure, low-pressure and exhaust steam; for hot and cold water; for brine and ammonia; for compressed air; and for wort and beer

FROM the engineer's viewpoint the brewing of beer is a cooking and cooling process and consequently steam, refrigeration and water piping are among the important services of the modern brewery. In addition compressed air, free of oil or other impurities, must be piped and carbon dioxide for the carbonating process is compressed.

As predicted by R. C. Doremus in an article in the January HEATING, PIPING AND AIR CONDITIONING, the legalizing of beer has been attended by strict taxation, the raising of revenue being one of the main considerations. As the brewing process itself requires a definite time cycle for the production of good beer those breweries which hope to profit must utilize modern steam and refrigeration equipment and properly-designed piping to secure manufacturing economies. Piping in the brewery must be designed in line with modern practice as, in the final analysis, the plant is no better than its piping.

Most of the beer available in the next few weeks will have been made in the breweries which have been producing non-alcoholic or near beer during prohibition years. Typical of such a plant is that of the Atlas Brewing Company, Chicago, which has been in existence since 1890, and after the prohibition law became effective, engaged in the manufacture of Atlas Special Brew. This brew is made in the same manner as beer, the alcoholic content being reduced to conform to the requirements of the law. Recently-legalized beer is now being made at this plant, the dealcoholizing process being modified.

At the Atlas brewery steam, refrigeration (ammonia and brine), cold water, hot water and compressed air are piped to various points in the beer-making and bottling process for the following services:

Steam at boiler pressure—125 lb: To brew kettles (reduced to about 35 lb), mash tubs, steam-driven water pump, uniflow engine driving generator, Corliss-engine-driven refrigerating compressors, engine-driven stokers, dealcoholizing (in winter—reduced to proper pressure by automatic thermostatic valve).

Exhaust steam: For water heating, pasteurizing, bottle sterilizing, dealcoholizing (in summer).

Hot water: To mash tubs, bottle washing and rinsing, boiler feed.

Cold water: To water section of hot-wort cooler, condenser requirements, emergency boiler feed.

Ammonia: Brine cooling, wort and beer cooling, room cooling (hops storage, fermenting room, stock tanks, government tanks, racking room.)

Brine: Circulated through attemperator coils in fermenting tanks.

Compressed air: For bottling machines, operating keg-filling machines, pitching machines, and many other minor uses.

Carbon dioxide: Compressed for carbonating.

In addition to these piping services, the wort and beer are piped through the various stages of the brewing

Thanks are due N. O. Kenniker, chief engineer of the Atlas Brewing Company, and Charles Ellman, brewmaster, for their cooperation in furnishing the information on which this article is based and giving permission for taking the photographs.

process from the mash tubs until the beer is finally bottled or kegged. The following description shows the part piping plays in the manufacture of beer at the Atlas plant.

The Beer-Making Process

Into one of the two mash tubs on an upper floor of the brew house go the malt and other ingredients—in proportions dictated by the brewmaster's specialized knowledge and under the careful supervision of his assistants—where mashing with hot water at temperatures close to the boiling point continues for two or three hours, steam at boiler pressure for heating being admitted to the tub through several nozzles. From a number of locations in the bottom of this tub copper pipes lead to the *grant,* a small copper header illustrated in Fig. 2. The several take-offs from the mash tub shown in the background are provided so that the wort resulting from the mashing process can be observed and tested by the brewmaster before it goes to one of the two brew kettles. The hot wort flows through the single copper pipe leading from the bottom of the grant to the brew kettle.

At the Atlas brewery two mash tubs, and two grants and two copper brew kettles on the floor below, are provided. They are cross-connected and properly valved so that wort from either of the mash tubs can flow to either of the brew kettles. Flanged copper piping is used for the hot wort to enable the piping to be taken down (this is required infringently) to clean it of the sugary deposit, *beer stone,* which tends to clog it up. Copper has been found satisfactory for this purpose at the Atlas plant as this deposit is not inclined to stick to copper as much as to some other materials. Rubber gaskets are used in the flanged joints.

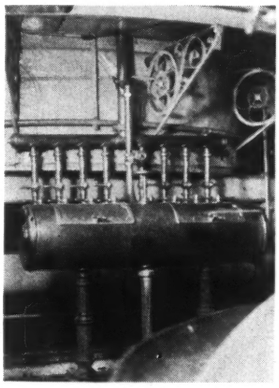


Fig. 2 (above)—From various locations in the bottom of the mash tub shown in the background the wort resulting from the mashing process is collected by the copper piping shown and conveyed to the grant, the small header shown here. The wort flows from the grant through the copper line from the bottom to the brew kettle

In this brewery it happens that one of the large brew kettles (shown in Fig. 3) is steam-jacketed and the other has a copper steam coil. Fig. 3 also shows the large copper vent pipe through which the vapors from the brew are discharged to the atmosphere. In this brew kettle the wort is boiled for perhaps an hour, the hops are dumped in, and the brew is boiled approximately half an hour more. Steam is furnished the brew kettles from the header in the boiler room and control is manual, although experiments are now being made at the Atlas plant on the application of temperature control to this part of the brewing process.

When this part of the brewing has been completed to the satisfaction of the brewmaster's assistant, who watches it constantly, the wort (at about 212 F)[1] flows through flanged copper piping to the next floor below and into the *hop jack* where the hops are strained out. This tank furnishes suction to a motor-driven centrifugal pump which pumps the hot wort (now at a temperature of 190-200 F) through a copper line to a tank on the top floor of the brewery. This pump is a standard water pump equipped with stainless steel shafts, sleeves, and wearing rings.

The wort must now be cooled quickly and this is done by letting it flow or rain over the outside of a Baudelot cooler. From the top-floor tank just mentioned the hot wort goes to the copper distributing tray above the cooler, flows through perforations in this tray, over

[1]The Reaumur temperature scale is extensively used in brewery work, in addition to the Fahrenheit and Centigrade scales. To change degrees Fahrenheit to Reaumur subtract 32 and multiply by 4/9; to convert from degrees Fahrenheit to Centigrade subtract 32 and multiply by 5/9.

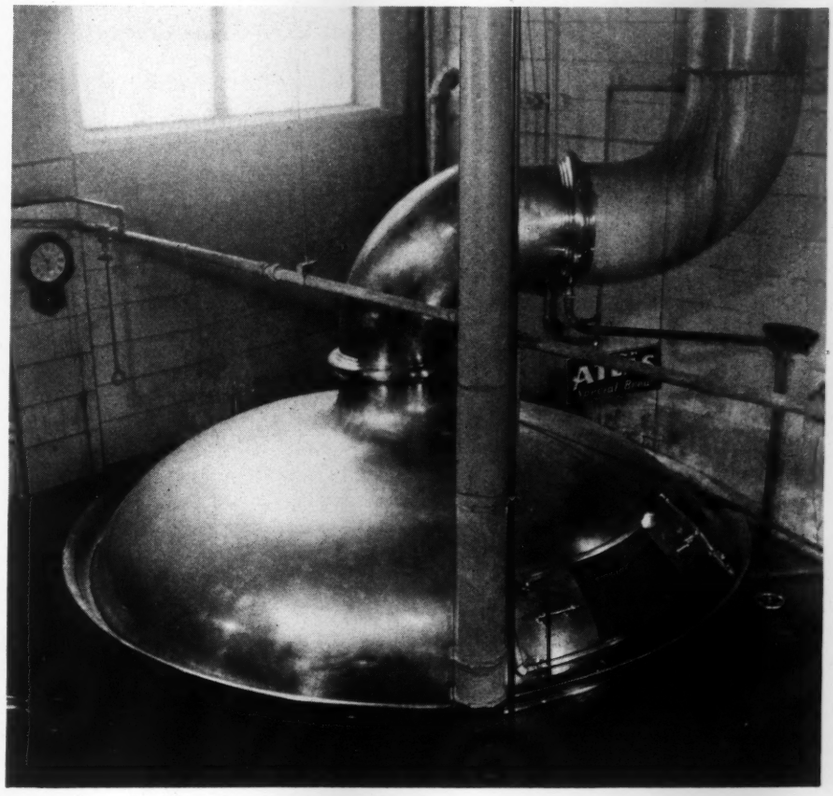


Fig. 3 (right)—The copper steam-jacketed brew kettle at the Atlas plant; a second brew kettle (not shown here) is of the same general appearance but has a steam coil instead of being steam jacketed. When brewing has been completed the wort is piped to a tank on the floor below, hops are strained out, and it is then pumped to an upper floor of the brewery

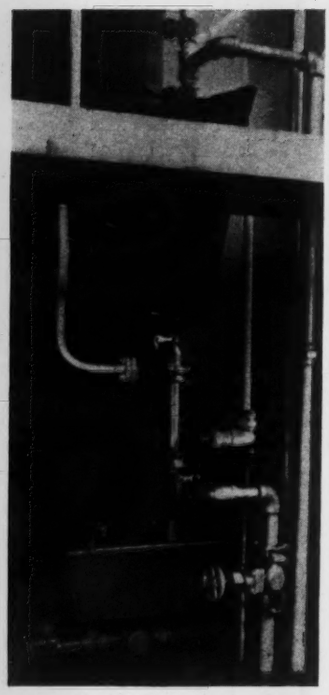


Fig. 4 (above)—One end of the hot-wort cooler on an upper floor of the plant. The hot wort rains over these horizontal pipes and is cooled. Through the upper two-thirds section of this cooler cold water flows, cools the wort and is itself preheated. Direct-expansion ammonia cools the lower one-third section. From here the wort goes to the settling, fermenting, and other process tanks through galvanized iron piping

Fig. 4. The water section of the cooler is made of copper piping and the ammonia section, iron pipe.

the cooler, and into a second copper tray at the bottom which catches the cooled wort, now at a temperature of approximately 45 F. Cold water from the house tank flows through the upper two-thirds section of the wort cooler, is preheated as it cools the wort and then flows by gravity to a hot-water tank on a lower floor, conserving the heat from the wort. The lower one-third section of the wort cooler is cooled by direct-expansion ammonia. One end of the wort cooler and part of the ammonia piping is shown in

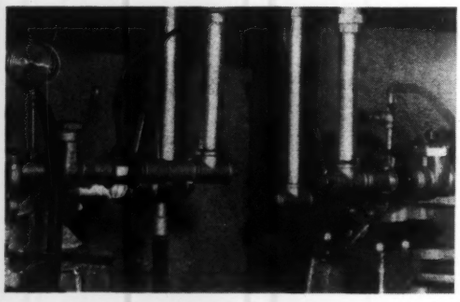


Fig. 5—After the beer has fermented and aged it is filtered. Shown here are the ends of two adjacent filters, and the sight glasses for observation of the clarity of the fluid

After the wort has been cooled it is piped in galvanized iron piping to the tanks in the various refrigerated rooms[2] for settling, fermenting, aging, etc., the result of which is the finished product—beer. Some of these tanks are large wooden casks, about 10 ft high and 6 ft in diameter. Others are of steel, enamel lined, to prevent contact between the beer and the metal. In the fermenting tanks, brine coils (attemperators) remove the heat generated by the fermentation. These coils are located in the upper parts of the tanks to improve cooling, as the warmer beer rises to the top and the cooler beer sinks to the bottom. Brine is supplied from a large brine-cooling tank on an upper floor of the brewery. Carbon dioxide gas is a byproduct of the fermentation process; this is reclaimed and compressed, passed through a scrubber and bottle at 250-lb pressure for use in the carbonating of the beer at a later stage in the manufacture.

The required temperatures in the various refrigerated rooms in a brewery must be carefully controlled at all times to prevent spoilage of the product.

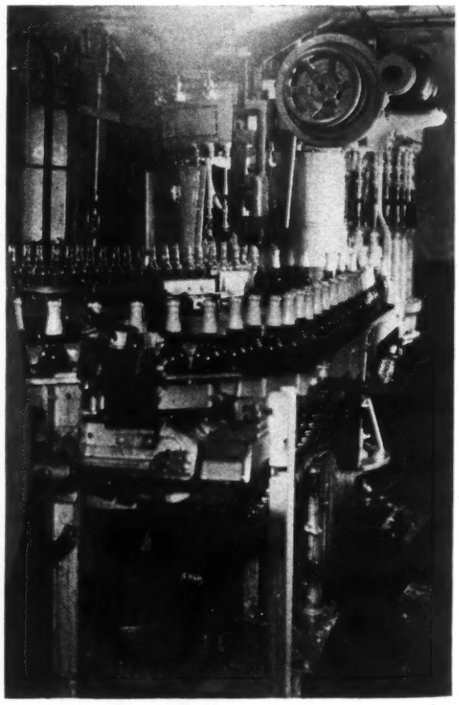
After the beer has been properly aged it is ready for carbonating, filtering, and bottling or keg-filling. The beer is piped to the filters through galvanized iron pipe and temporary hose connections where it is passed through several layers of cloth filter material; the ends of two adjacent filters are shown in Fig. 5, which illustrates the sight glasses through which the clarity of the filtered beer can be observed. From the filters the beer can be piped to the keg-filling machine or through an underground copper line to the bottling-house storage tanks. (The bottling house is separated from the building in which the filter equipment is located by a railroad siding.) About 70 per cent of the product is bottled and 30 per cent is sold in kegs.

Bottling the Beer

In Fig. 6 is shown one of the machines in the bottling house which can fill and cap about 7,000 bottles per hour. In the background can be seen the line of empty, clean bottles entering the machine, which revolves continuously. As the bottles revolve on the machine they are filled with beer. When a bottle completes one circuit it is completely filled and automatically capped. The bottles then leave the filling machine via the conveyor shown in the fore-

(*To page 77, back Advertising Section*)

Fig. 6 (below)—Beer is piped to the bottling machines from storage tanks in the cellar of the bottling house. Compressed air is also piped to operate these machines. Steam and hot water are required by the bottling department for sterilizing, washing, rinsing and pasteurizing



[2]For an outline of the requirements for the various refrigerated rooms in a brewery see "Legalizing Beer Means Modernization of Old Breweries," by R. C. Doremus, p. 18, January, 1933, HEATING, PIPING AND AIR CONDITIONING

Data Sheets for Calculating

HEATING SURFACE FOR BUILDINGS

THE graph on the next page is the first of a series designed to enable computations for heat losses from buildings to be made accurately, with the minimum of time and with decreased possibility of errors. All are based upon a lowest recorded temperature of —6 degrees Fahrenheit and a 61-degree temperature difference which, if the base temperature is taken as 15 degrees above the lowest recorded temperature, will permit their direct use in Philadelphia and New York. There is also a chart showing the proportionate heating surface required for other climatic conditions. Used in conjunction, they are applicable to any condition.

The "curves" are for various coefficients of heat transmission. As an example of their use, assume 160 sq ft of exposed wall having a coefficient of heat transmission of two-tenths. Reading vertically below the intersection of the horizontal line for 160 sq ft and the "curve" for 0.20, it is found that 8.1 sq ft of heating surface would be required to compensate for this loss. If the wall is on the side of the building swept by prevailing winds, the scale on the upper edge of the chart is used instead of that at the bottom, and it is found that 9.3 sq ft would be required for this condition. If the lowest recorded temperature for the locality is —30 degrees, it is found from the chart showing proportionate heating surface required, that the amount already determined must be multiplied by 1.4. In using this chart, it is recommended that the multiplier be applied to the total heating surface determined from the transmission charts for a whole space, rather than each loss from that space.

This series of charts is composed of first, six charts for transmission losses for coefficients from 0.02 to 1.12 and for exposures up to 500 square feet. Second, a graph from which may be determined the heating surface required for infiltration up to 26,400 cubic feet. Third, a chart giving the proportionate heating surface required for climatic conditions other than those upon which the other graphs are based. Fourth, a chart giving the pounds of steam and equivalent direct heating surface required for heating domestic hot water through temperatures from 100 to 140 degrees. Every month one or more of the charts will be printed until the series is complete.

By Price L. Rogers
Consulting Engineer, Philadelphia, Pa.

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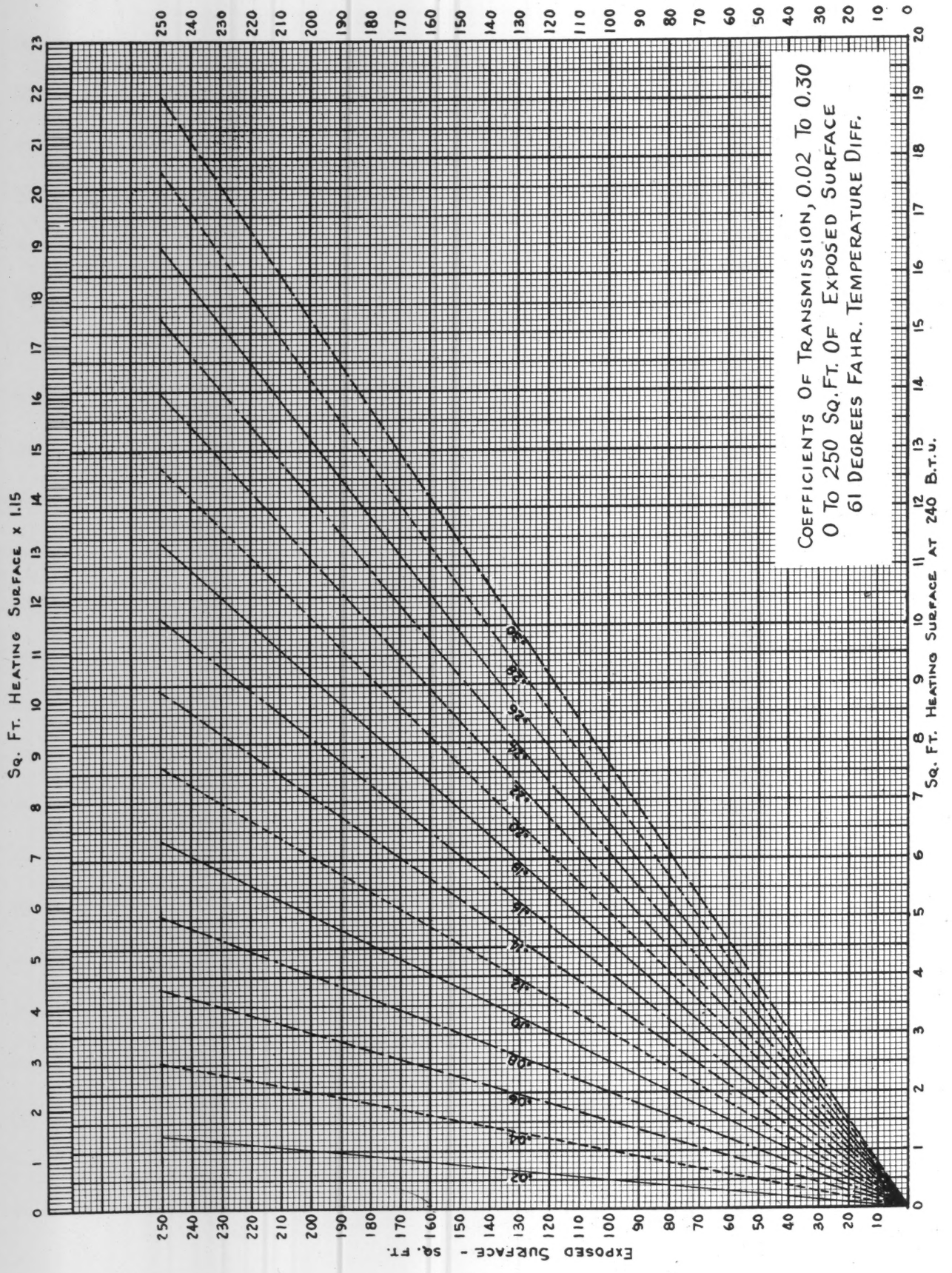
Calculating Heating Surface for Buildings 1



Novel Control for Operating Pump

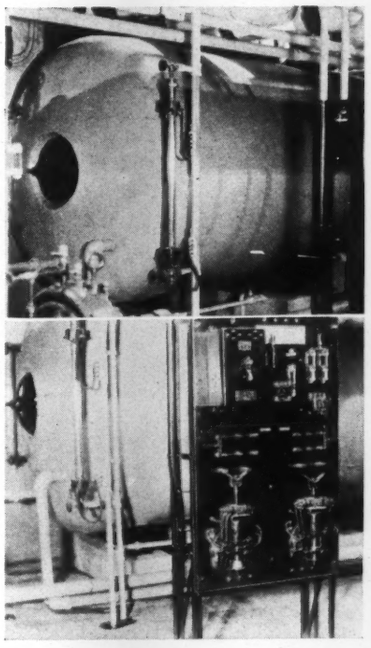
By **Henry G. Schaefer**

A CONTROLLING device for operating a pump for emptying a blow-off or other closed tank, and to function within predetermined levels of the tank contents, which eliminates the problem of keeping a stuffing box tight to prevent leakage and has no float is illustrated here. It is applied to a blow-off tank in a plant. Its operation depends on an electromagnet.

The upright tube resembling a gage-glass is built of brass and connected to the tank at top and bottom so that in effect it provides a level gage. Within this tube is a short piece of iron tubing fitting loosely so as to permit it to move freely up and down. The ends of the tube are sealed so as to make of it a float. As the level of the tank contents varies, the iron tube floats at the surface. Mounted on brass sleeves, two coils of magnet wire are provided around the upright tube. The height at which they are located is instantaneously adjustable since the lead-wires are flexible and the brass sleeves carry thumb-screws for holding the coil in a fixed position.

Through the variation in the current characteristics induced by the introduction of the floating core into the field of the upper winding a combination of solenoid actions starts the pump. When the float reaches the field of the lower coil a similar electromagnetic action shuts down the pump, leaving the automatic controller ready for the next starting operation.

The only vulnerable part of the equipment is the small float, which, beside being readily replaceable by the removal of the valve controlled "float chamber" by breaking two 1½-in. ground-joint brass unions, is inexpensive. This unit has been in operation for four years with two float replacements, each accomplished in twenty minutes without any attempt at rushing.

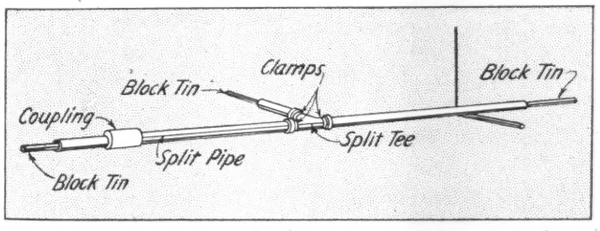


Two views of the pump control device which maintains contents of this blow-off tank between pre-determined levels; operation depends on an electromagnet. Two float replacements have been necessary during four years' operation, each being accomplished in twenty minutes

Runs Block-Tin Pipe in Steel Pipe

By **George Hall**

GOVERNMENT specifications on the block-tin piping for distributing distilled water in the recently-completed Forest Products Laboratory at Madison, Wisconsin, required that it should be fully encased within a larger size steel piping system. How to form a block-tin pipe tee within a steel tee was the problem which had to be solved by the contractors, W. J. Hyland Co.



How a tee for the block-tin piping was made within the encasing steel tee. Note that only a short length of pipe was split (from tee to coupling) and that three wire clamps hold the assembly in place. The tee and coupling hold the split pipe together

According to the specifications, extra-heavy block-tin pipe carried in 1-in. galvanized pipe (and run along the same trapeze hangers which support the other service piping) was used. As there were in all about forty openings on the various floors, a large number of solder joints to the main run for the branches to the laboratories was necessary. Attempt to have the requirement changed to permit the use of square conduit at the ceiling, which would have made available the use of outlet boxes for the tee branches, was made without success. The contractor's foreman finally hit on an ingenious way around the difficulty.

Using a coupling about 12 in. from the joint, he split the pipe up to the tee. The tee also was split and after making his soldered connections he clamped his pipe and tee in place and continued. A very close examination would be necessary to disclose the split.

The sketch shows how the work was done. The clamps consisted merely of a single wrapping of wire with the ends twisted together tightly. Only three clamps were used at each tee, one being placed at each opening. Since the split pipe fitted into the solid coupling, no clamp was necessary there.

Usually, when block-tin piping is installed for distributing chemically-pure water, the piping is laid in open troughs suspended from the ceiling. However on this job it was deemed advisable to protect the tin piping more completely as its mechanical strength is of course low.

Psychrometer Has *Two* Wet Bulbs

PRECISE measurement of humidity from zero to nearly saturation, and at air temperatures up to at least 150 F, is possible with an improved psychrometer developed at the Bureau of Standards, according to a release received from Lyman J. Briggs, acting director. While the instrument has not been used at higher temperatures, a number of measurements of humidities less than 5 per cent, at temperatures above 140 F, showed the average error to be less than ¼ per cent.

This instrument, which is but slightly more complicated than the ordinary ventilated psychrometer, is novel in that two wet bulbs are used. The tube supplying water to the thermometric wet bulb is perforated and jacketed with a wick exposed to the air stream, and thus constitutes a second wet bulb. The supply tube serves to pre-cool the thermometric wet-bulb water supply to evaporation temperature. This has been found essential to precision of measurement under conditions causing large wet-bulb depressions. In addition, precision at high relative humidity is improved.

Tests on several models of this type of psychrometer covering a range of dry-bulb temperature from freezing to 150 F, of relative humidity from 0.5 per cent to 87.5 per cent and of air pressure from normal sea-level pressures to a pressure as low as that found six miles above sea level, have shown that, with careful handling, the precision of humidity measurement depends only on the precision of the thermometers used. In other words, the wet bulb reaches the true evaporation temperature under any of the above conditions.

The customary formula or tables consequently apply for this apparatus over the wider ranges mentioned. However, a new chart has been prepared which gives either relative or absolute humidity more simply and more exactly than present charts. This chart will appear shortly in the *Journal* of the Washington Academy of Sciences.

Check Drives When Modernizing

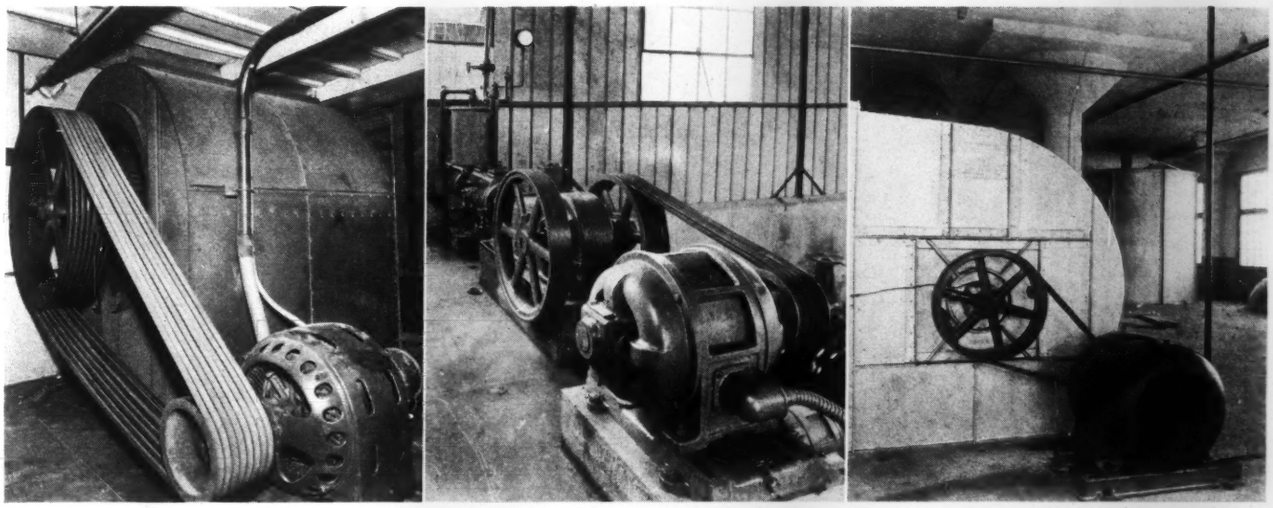
By W. A. Meyer*

REHABILITATION or modernization is receiving unusual attention among industrial leaders throughout the country, a movement of economy and preparedness. It is a signal for everyone to see that all machinery is placed in working order and on an efficient basis. Many machines have been neglected during the past three years, many are worn beyond repair, many have been obsoleted by modernization. This prompts a careful survey of conditions of ventilating fans and blowers, compressors, pumps and unit heaters installed in heating, piping and air conditioning systems in industrial plants, office buildings, hotels, hospitals, schools and other large buildings and in this connection the power transmission equipment should receive the attention its importance in efficient, economical plant operation deserves.

Perhaps a pump should deliver more water, a compressor more pressure or a fan more air, or perhaps other alterations call for a more compact arrangement of such equipment. Noisy machinery is certain to cause annoyance and discomfort in serving those for whom the equipment is intended. Cost of operation is certainly important.

To get the full capacity out of a pump, a compressor or a fan, a highly efficient type of drive is of paramount importance. If the drive is one of those installed in the "good old days" it is safe to assume that the efficiency of the transmission equipment falls in the range of 90 to 95 per cent efficiency. Every engineer interested in modernization will make a special effort to determine the efficiency of his transmission equipment because it is not infrequent that losses of 5 to 10 per cent occur through inefficient drives. Properly designed V-belt drives can show an operating efficiency of 98 to 99 per cent which will result in a considerable saving in power bills.

*Allis Chalmers Manufacturing Company, Milwaukee, Wis.



Acceptance by American industry of the value of modernization prompts a careful survey of existing drive equipment to increase efficiency of heating, piping and air-conditioning systems and cut power costs. V-belts may be the answer in many cases. Left to right are shown: 100-hp V-belt drive operating a supply fan; V-belt drive operating a compressor in the oil industry; V-belts driving a fan in a packing house

High-speed motors with V-belt drives make possible high power factors where reasonable attention is given to proper loading of motors. Installations are on record where the power factor was increased from 75 to 85 per cent by means of V-belt drives and high-speed motors.

Ordinarily a power factor of 80 per cent may be considered satisfactory where the customer is generating his own power or if power is purchased where no penalty for power factor is attached. Where, however, the local power company enforces a heavy penalty for power factors below 85 per cent this phase of operation is well worth careful consideration.

"Fan Engineering" Completely Revised

The third edition of "Fan Engineering," which has recently been published by Buffalo Forge Company, Buffalo, N. Y., has been completely revised and contains considerable information which has not before appeared in this standard reference handbook. Over 100 pages have been added on the subjects of air, fans, and fan applications, including new sections on cooling and air conditioning.

Printed on thin India paper and bound in morocco Fabrikoid, this book is of convenient size though it is 622 pages in length. Its price is $3.00.

Part I on the physics of air consists of the following chapters: Properties of Air, Humidity and Heat; Air Flow; Proportioning of the Flow in Pipes; Air Flow in the Fan. Part II on air conditioning and other fan applications contains chapters on heating, ventilating, humidifying and dehumidifying, cooling and refrigeration, drying, combustion and mechanical draft, dust elimination, and exhausting and conveying. Part III (Fans and Air Conditioning Equipment) consists of: Selection of Fans and Apparatus; Fan Details; Multiblade and Miscellaneous Fans; Heaters; Coolers; Air Washers; and Power Equipment. An appendix is devoted to specifications, guarantees, codes, and miscellaneous data.

Knudsen's "Architectural Acoustics"

Considerable information of value to the heating and air conditioning engineer or contractor is contained in Prof. V. O. Knudsen's "Architectural Acoustics," which is published by John Wiley & Sons, Inc., New York City. Prof. Knudsen will be remembered by readers of Heating, Piping and Air Conditioning as the author of the article "How Sound Is Controlled," which appeared in the October, 1931, issue and which has been quoted in many articles and reference books.

"Architectural Acoustics" is a reference and text book of 617 pages and comprises a full discussion of both the principles and practices in the field of architectural acoustics. Part I, on physical and physiological acoustics, is divided into chapters on the nature of sound, of hearing, and of speech and music. Part II, on fundamental principles and data, includes sections on reverberation of sound in rooms, absorption of sound, insulation of sound, amplification of sound, and acoustics of auditoriums, speech halls and music rooms. Part III relates to applications to building design and has chapters on school, public and commercial, and church buildings; open-air theaters; theater and music buildings; hotels, apartment houses and residences; and radio broadcast and sound-recording rooms. The price of this book is $6.50.

Pamphlet on Greenhouse Heating

A 40-page pamphlet (Circular No. 254) on greenhouse heating has been published by the Department of Agriculture; the author is Arthur H. Senner, of the bureau of agricultural engineering. It presents standard engineering data on this subject and practical information with regard to the layout and operation of modern heating systems.

For Testing Castings, Forgings, Welds Navy Uses

RAYS FROM RADIUM

By - - - - Charles S. Barrett, Ph. D.*

READERS of this magazine are familiar with X-ray radiography, which has been increasingly used in recent years as a non-destructive test of castings, forgings and welds, and which is of service in the testing of piping for high-pressure and high-temperature steam. A new but closely related method of radiography with characteristics less familiar at present to most engineers has emerged from the laboratory and is now taking a place in testing work; this is radiography by the use of gamma rays, developed during the last four years at the Naval Research Laboratory in Washington under the direction of Dr. R. F. Mehl, and now in use by the Navy.

The Nature of Gamma Rays

Gamma rays are extremely penetrating rays given off by certain radioactive substances as they spontaneously disintegrate. We speak of gamma rays from radium but that is not strictly accurate for the rays are not actually emitted from this element; they come from the elements that form from radium by successive atomic transformations. These elements may either be left sealed with the parent radium in capsules, such as that shown in Fig. 1, or they may be removed from it from time to time as they form and sealed into capsules. When these decomposition products are left sealed with the radium from which they form they continue to issue gamma rays of practically constant intensity, for they diminish only as fast as the original radium. This decreases logarithmically to 50 per cent its initial value in 1,580 years. However, when the decomposition products are separated from the parent radium the gamma-ray intensity from them decreases as fast as does radium emanation, which is the first number of the series of decomposing elements. Radium emanation (radon) decreases logarithmically to half its initial strength in about four days. Its strength at any time can be determined from the simple exponential equation of decay, or by reference to tables which give the strength hour by hour. The strength at any time is definite and the rate of decomposition cannot be varied by artificial means. Either radium or radium emanation may be used in radiography with equal results; in this article the remarks about radium are intended to cover radium emanation also. The choice between the two depends upon cost, availability or convenience.

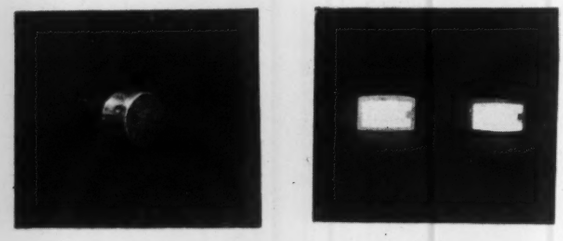


Fig. 1—Model of a capsule of radium designed for radiography; its diameter is that of a lead pencil. At the right it is shown cut in two

The Process of Radiography with Gamma Rays

The process of making a radiograph with gamma rays consists of mounting the capsule of radioactive material in an appropriate position in front of the piece to be examined, attaching a radiographic film in a light-tight holder to the back side of the piece, and exposing it there for a definite length of time to the rays which have penetrated the object (See Figs. 2 and 3). At the end of the exposure the film is removed and developed. It then exhibits a shadow image of the surface irregularities and the interior defects of the object.

The length of exposure required to obtain a picture of good quality can be predicted with precision once the conditions are known under which the exposure is to be made. A long exposure with a small amount of radium may be used, or the same results may be had with a larger amount of radium in a correspondingly shorter time, for the length of exposure is inversely proportional to the intensity of the source.

The intensity of gamma rays varies as the inverse square of the distance from the source. Hence the exposure necessary increases directly as the square of this distance, that is, the distance from the radium to the film. A suitable distance between radium and film is decided upon after considering the physical dimensions of the radium capsule and the size and shape of the objects to be radiographed, bearing in mind that increasing this distance will increase the length of exposure but will also improve the sharpness of the registration of defects on the radiograph.

The principal factor governing the length of exposure is the thickness of the object through which the rays are to pass. For example in the case of the radiography of iron and steel the exposure required approximately doubles with each added inch of thickness to be penetrated. Using a set of charts on which strength of source, distance from source to film, and thickness to be penetrated, are correlated, the proper exposure for a given set of conditions may be quickly determined.

*Naval Research Laboratory, Bellevue, Anacostia, D. C.
† Published by permission of the Navy Department.

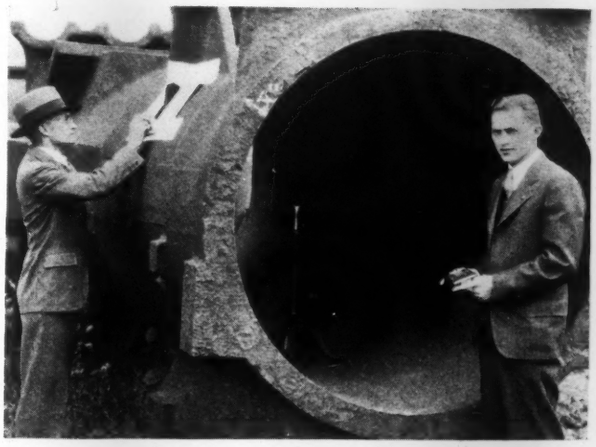
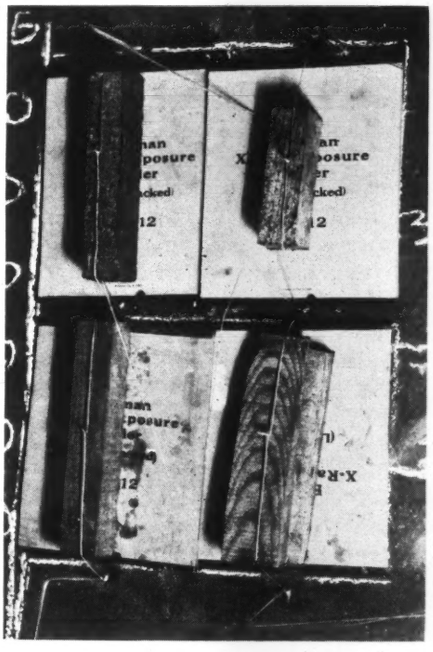


Fig. 3 (right)—Radiographing a large cylindrical casting by placing radium inside and fastening films outside

Fig. 2 (below)—Films in their holders attached to a casting during a gamma-ray exposure



It is common practice to radiograph a casting just as it lies on the foundry floor. Surface irregularities will make their impression on the radiographs, of course, but these are usually recognized and disregarded; in fact a few of these are usually welcomed as landmarks to aid in determining the exact location of interior defects.

The developing of gamma-ray films may be done exactly as is done with X-ray films, although certain modifications of it are advisable to increase efficiency with gamma rays. The dark room facilities needed and the films themselves are the same, at the present time. As to the interpretation of gamma-ray radiographs, while it is true that an expert will notice significant markings that a beginner would often overlook, a person familiar with the defects that are apt to be encountered in the object can learn to identify them on the radiographs with little experience or instruction. Radiographs frequently resemble in a striking manner the object they represent if the object is machined so as to expose the defects which appear on the radiograph.

Exposures for the average run of steel castings require, in general, a matter of a few hours when one or two hundred milligrams of radium are used. To handle thicknesses of the order of 4 and 6 in. it is convenient to start the exposure in the afternoon and let it run throughout the night, placing the material so as to be fully exposed at any desired time the next morning. The equipment does not require the operator's attention during the exposure; his time is free for preparing another exposure or developing films from a previous one.

Inspecting Flanges in Installed Line

Since radium emits rays of equal intensity in all directions, castings may be piled all about the radium and exposed simultaneously. If the object is spherical or cylindrical in shape the radium can be placed in the center and films all around the outside will be exposed at the same time as illustrated in Fig. 3. Using this principle, 20 sq ft of 2-in. material has been radiographed with one exposure, and in one case this area could have been trebled if it had been necessary. This arrangement may be used to advantage in testing piping for high-temperature or high-pressure steam installations; thick flanges may be covered with one exposure to gamma rays if the radium is located on the centerline of the pipe. The possibility of placing the capsule of radium inside complicated structures and in places difficult to reach often makes possible the testing of materials when they are in place in a completed structure.

Radiography by gamma rays offers a non-destructive method of testing, possessing simplicity, portability and safety. The technique has developed with rapidity; it is now possible to radiograph an object in one-twentieth or one-thirtieth the time that was required four years ago; in other words, a given quantity of radium is twenty or thirty times more effective in radiography today than it was then. This acceleration has come largely through the use of photographic materials of increased efficiency and perhaps more will be accomplished by further research along this line. That the method actually does register accurately the interior condition of an object has been proved repeatedly by checking the radiographs against physical examination. It has been successfully applied in practice to objects from ¼ in. to 6 in. in thickness, and in the laboratory to 8 in. and 10 in. specimens. Sufficiently prolonged exposures will penetrate even greater thicknesses, the upper limit of which is not yet known.

INTERESTING Equipment..... Developments

Meter Oils, Chemicals, Foodstuffs

The Brown Instrument Company has developed a new flow meter to measure the flow of certain fluids, such as heavy oils, chemicals, foodstuffs, etc. Seals and auxiliary piping between the meter body and pressure taps are not required by this area-type flow meter because the meter body is installed directly in the pipe line and a recording or indicating meter at any location is connected to it electrically

This meter is particularly adapted to measuring the flow of heavy oils, which must be heated to flow freely, as the meter body is right in the line and if the oil will flow through the line it will flow through the meter body. It is also suited to measuring flow of various chemicals, eliminating problems arising from corrosion and contamination. In measuring the flow of foodstuffs such a meter is advantageous as it will not affect the purity or quality of the liquid measured, according to the manufacturer.

The meter body is of a piston and sleeve type. The flowing fluid enters the meter body at the entrance, passes under the piston, through an orifice, and is discharged. As the fluid enters the meter body it strikes the bottom of the piston. Since the piston is free to slide vertically upward, it will be lifted, exposing a section of a rectangular orifice in the sleeve. As the fluid escapes through this orifice, it rises through a pulsation throttling orifice in a vacant section above the piston. This will exert a vertical downward force on the piston.

The position of the piston is measured by an inductance bridge system. As an armature travels vertically in a non-magnetic tube, surrounded by a divided inductance coil, another armature in the receiving meter will assume corresponding positions which will be a measure of the area of orifice opening in the meter body, and hence the rate of flow.

The meter is calibrated to give equal increments in deflection for equal increments in flow, hence the scales and charts are evenly graduated. The forces which shift the piston position are actually as great at small flows as at large flows, and this makes the meter accurate at low flows as well as at large flows.

For measuring water (or fluids having approximately the same specific gravity) the ranges vary from 0-150 gph minimum to 0-2000 gph maximum. The meter capacity is less for fluids having a specific gravity less than that of water. For example, for a fluid whose density is one-half that of water, the maximum capacity of the meter is only 70 per cent of that when water is measured. It is furnished in one pipe size only, 2 in. Where the pipe line is smaller or larger than 2 in., a section of 2-in. pipe is inserted for a distance of 15 pipe diameters on each side of the point in the line where the meter body is to be installed.

A complete installation consists of the meter body, recording or indicating meter, and connecting wire. The receiving meter can be located at a remote point from the meter-body and can be had in several types. The inductance-bridge principle makes it possible to operate two receiving instruments from one meter-body. This means a circular chart recorder and a circular dial indicator can be operated in parallel off one meter-body. This feature is often taken advantage of by installing the indicator near the operator's post and the recorder in the engineer's office.

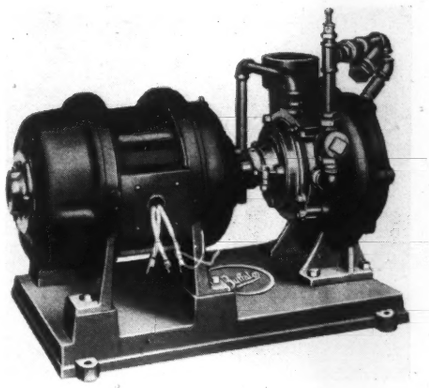
New Single-Suction Pump

A new single-suction pump with built-in self-primer for general service work has been designed by Buffalo Pumps, Inc., Buffalo, N. Y.

The casing is cast iron, and suction side-plate is template-drilled, with close clearance with impeller. Two types of impellers are available; on sump service, or wherever liquids are not clear, the open type is recommended, while for all services where clear liquids are pumped, the enclosed impeller is commonly supplied. For general service, bronze impellers are used, but where required, cast iron or other metal is furnished.

The self-priming device is mounted as an integral part of the pump casing. The pump shaft, bronze covered, is an extension of the motor shaft, carrying impellers for pump and primer. With this construction no bearings are used in the pump, both radial and thrust loads being taken by motor bearings; and, of course, no coupling is required.

The gland is a split type, cast-iron regular equipment,

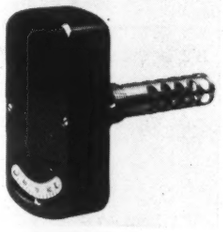


bronze being furnished on special order.

The pump is furnished complete with all necessary fittings and is built in several sizes in capacities up to 450 gpm and for heads up to 150 ft.

Non-Corroding Thermostat

A three-wire, low-voltage, duct-type thermostat that will not corrode and consequently may be used where exposed to water vapor has recently been introduced by Barber-Colman Company, Rockford, Illinois. All parts of the instrument which are exposed to the vapor are made of phosphor bronze with the exception of the sensitive element which is of bimetal. Models are now available in the standard ranges. In general appearance this new instrument resembles a regular duct thermostat.



New Electric-Weld Boiler Tubes

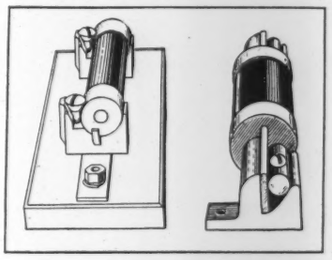
Steel and Tubes, Inc., Cleveland, Ohio (subsidiary of the Republic Steel Corporation), has announced the development of electric resistance weld boiler tubes which have been recommended by the *American Society of Mechanical Engineers* for use in pressure boilers, and bear the approval of both the United States department of commerce steamboat inspection service, and the American Bureau of Shipping.

The tubing is formed from strip steel continuously, the strip being passed through a series of forming rolls. The round butted tube thus formed then passes under revolving wheel-like copper electrodes where current travels from electrode to electrode through the butted seam of the tube. At the same time, pressure is applied which, together with the heat which is below the fusion temperature and which is confined to an area the size of a pinhead, completes the weld. The tubing is later normalized and tested in accordance with *A.S.M.E.* specifications. Among the features of these tubes are uniformity of diameter and wall thickness, and a fine strip steel surface quality inside and outside the tubes.

This tubing is available in all sizes up to 5 in. O.D., in copper bearing, nickel steel and Toncan iron, as well as open-hearth steel.

Fuse Clamps of "Vise" Type

The Trumbull Electric Mfg. Co., Plainville, Conn., has announced the addition of vise-type fuse clamps to its 30-ampere, 230-volt fusible switches, which now makes this entire line of switches available with these clamps in capacities from 30 to 800 amperes.



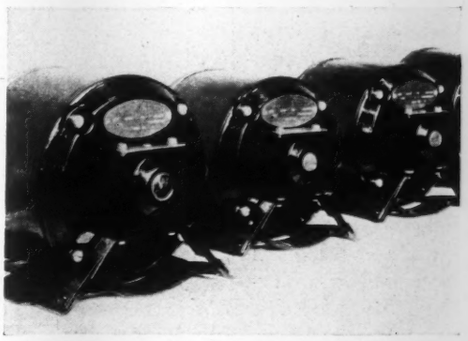
Tests reported by the maker have shown that this pressure type of clamp reduces heating, thereby preventing premature "blowing" of fuses.

Motor Is Self Protecting

A self-protecting motor which cannot burn out and yet carries overloads just as long as the motor itself is not in danger has been announced by the Westinghouse Electric & Manufacturing Company, East Pittsburgh, Pa. A small disc-type thermostat mounted on the motor frame opens the circuit when the motor gets too hot and connects it again after the motor has cooled. The motor is suited for automatically controlled devices, such as oil burners, air conditioners, etc.

Because the thermostat is arranged accurately to gage the temperature inside the motor, it lets the motor work as long as possible regardless of service conditions, but removes it from the line when the temperature approaches a damaging value. The thermostat's operation depends upon a combination of the actual motor frame temperature and the line current through the motor. At each load up to the pull-out point of the motor, there is a definite length of time required for the motor to reach the temperature which causes the thermostat to open its contacts removing the motor from the line. The higher the overload the sooner the motor disconnects itself. Different surrounding temperatures are also taken into account, the motor carrying a given overload longer in a cold room than in a hot one.

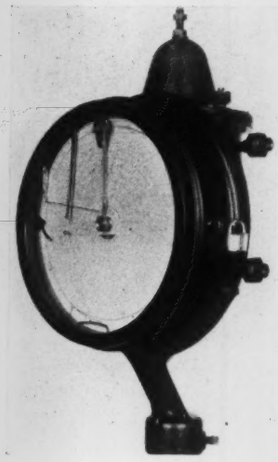
The thermostat has one moving part consisting of a circular bimetallic disc, which buckles at definite tempera-



tures, opening a multiplicity of contacts at a predetermined temperature and closing them when the disc cools down. This action occurs when the disc itself reaches its operating temperature, regardless of how the heat is supplied.

Flow Meter for Gas, Air

The Foxboro Company, Foxboro, Mass., has incorporated a number of features in a new bell-type meter for measuring the flow of gas or air at low pressures. One of the features of this new meter is compactness. One meter can measure 1,000,000 cubic feet per hour. In addition, should the flow conditions change and a meter of greater or less capacity be required, the same instrument can be adapted to the new conditions by installing an orifice plate of the correct size.

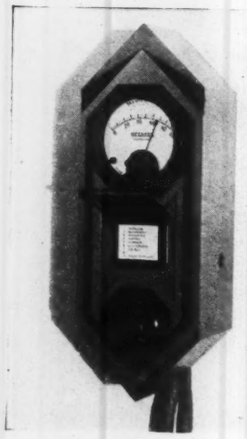


The bell-type meter may be furnished with any of the standard primary devices—orifice plate, pitot tube, flow nozzle or venturi tube, making it available for use wherever low pressure loss is desirable. The instrument is built ruggedly and is not materially affected by vibration or changes in leveling, according to the manufacturer.

Ranges of 2.5, 5, and 10 inches of water differential may be furnished. The meter may also be used in wide-range meter settings with meters of higher ranges.

Shows Several Temperatures

In many industrial processes, better results can be obtained if the operator can read at one central regulating point the temperatures existing at various remote points. For such applications a new temperature indicator of the electrical type is now available from the Westinghouse Electric & Mfg. Company, East Pittsburgh, Pa., which furnishes a means of accurately measuring the temperatures at as many as eight different locations. The instrument is 8½ in. high, 3 in. wide, and 2¾ in. deep.



The Wheatstone Bridge principle is used, with a sensitive search coil located at each of the points where the temperatures are to be measured. Voltage is supplied to the bridge from 110-volt, 60-cycle alternating current outlet.

Provision is made for calibration of the device for any voltage within the limits met on commercial lighting circuits and a "check" position on the dial facilitates checking the instrument. For cable runs of over 25 feet, three leads are run to each search coil, and for distances of less than 25 feet, two wires are used.

New 3-Hp Motors

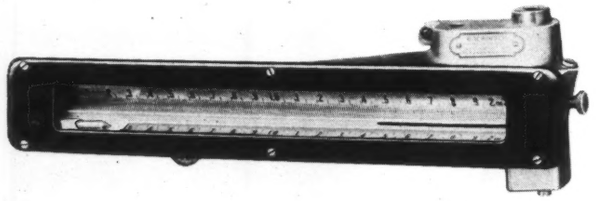
Announcement of a new line of 3-hp motors has been made by Emerson Electric Mfg. Company, St. Louis, Mo. The new motors operate at 1725 rpm and are furnished in the single-phase, repulsion start induction type, the polyphase squirrel-cage type and direct current, compound wound.

Frames are of rugged construction. The shafts are of tool steel. Bearings are of bronze, wool packed. Oil reservoirs are ample to make infrequent relubrication necessary.

The motors are designed to operate continuously without overheating. The frames have ventilating openings and a fan on the armature shaft provides air circulation through the motor. Ventilating openings are so arranged that protection is afforded from damage from dirt or water falling from above.

Inclined Draft Gage

The inclined-tube manometer illustrated here is made by the Bacharach Industrial Instrument Company, Pittsburgh, Pa., and may be had in five different ranges.

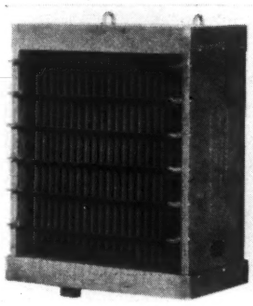


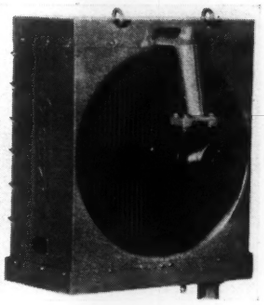
The body is a one-piece aluminum casting designed for maximum strength and the part that houses the scale and the indicating tube has a V-shaped cross-section for protection to the tube and visibility of the scale. A removable glass front protects against dust and moisture.

Scale adjustment is accomplished by turning the knurled thumb screw at the right. There are two pressure connections located close together at one side of the instrument, which may be used for measuring pressure, draft or differential pressure. Separate filling and vent holes are provided and filling or draining the instrument may be done without breaking the connections.

New Cooling Units

Cooling units in six different physical sizes have recently been made available by the Young Radiator Company, Racine, Wis., for air conditioning restaurants, hotels, barber shops, beauty parlors, department stores,





offices and other rooms. Three styles, one with a chromium-plated casing, a second with a pure copper casing, and the third with two finishing coats of olive drab paint are offered. Capacities range from 550 to 3800 cfm of air.

This unit can be used for cooling in summer and heating in winter; it is equipped with vertical moisture eliminators and a pan for collecting the moisture condensed from the air, in addition to horizontal louvers for deflecting the air in the proper direction. When used as a heater, the moisture eliminators are removed and adjustable air deflectors are fitted in their place.

The cooling or heating element is composed of flat copper tubes $\frac{3}{16}$ in. wide set in line, and to which are fastened flat copper fins. The header sheet is a heavy copper plate with the shape of the tubes pressed in the sheet and the excess metal pressed downward. The plate is then assembled to the condenser tubes and a metal-to-metal bond created by a process of brazing the header sheet and tubes.

The fins are stream-lined and fused to the tubes with an alloy coating over the entire condenser core; the core is tested to withstand 250-lb hydrostatic pressure.

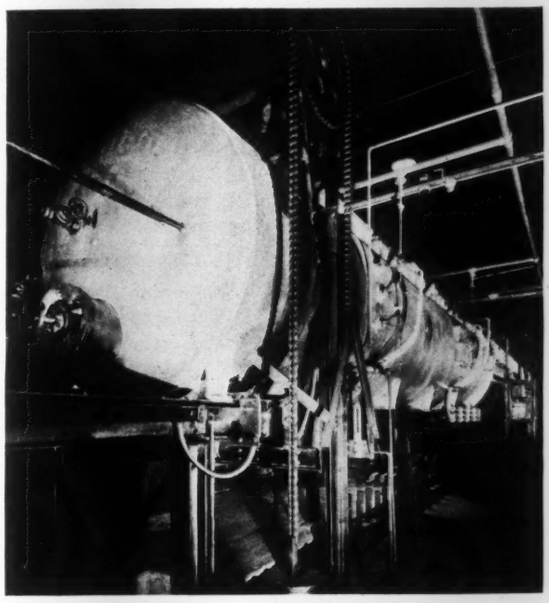
The cooling medium may be ice- or mechanically-refrigerated water, or water from a deep well.

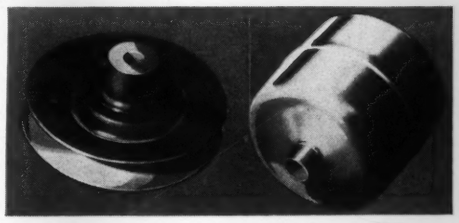
Motors may be had in either ball-or sleeve-bearing types, single- or multi-speed, the latter being recommended.

Parts Welded in Hydrogen

The "Zeppelin" type electric hydrogen-welding furnace shown here is in the plant of the Bundy Tubing Company, Detroit, Mich. In operation the parts to be welded are assembled by a snug fit, by inserting one part into the other or by spot welding or pinning the parts together. Copper in the form of copper wire or copper paste is applied at the joint and the assemblies are loaded on to cars which are automatically elevated into the hydrogen-filled heating zone of the furnace. The hydrogen atmosphere reduces oxides, scale, and other foreign matter on the surface of the parts and provides chemically clean surfaces for the welds. The iron and copper alloy together, some of the copper going into solid solution in the steel, and some of the iron being dissolved by the copper to produce an integral copper-iron alloy bond.

The second illustration shows a fan pulley manufactured from a hydrogen-welded assembly made up of two stampings and a screw-machine bushing, and a float made by this process. A header for a multiple





refrigeration installation was assembled by hydrogen-welding from a length of tubing, stamped end-plate and screw-machine fitting.

Conventions and Expositions

National Warm Air Heating Association: Mid-year convention, June 6-8, Hotel Stevens, Chicago. Managing director, Allen W. Williams, A. I. U. Building, Columbus, Ohio.

American Oil Burner Association: Annual convention, June 12-16, Hotel Stevens, Chicago, Ill. Secretary, H. F. Tapp, 342 Madison Ave., New York City.

American Society of Heating and Ventilating Engineers: Semi-annual meeting, June 22-24, Hotel Statler, Detroit, Mich. Secretary, A. V. Hutchinson, 51 Madison Ave., New York City.

American Society for Testing Materials: Annual meeting, June 26-30, Hotel Stevens, Chicago. Secretary, C. L. Warwick, 1315 Spruce St., Philadelphia, Pa.

Midwest Engineering and Power Exposition: June 25-30, Coliseum, Chicago. Headquarters, 308 W. Washington St., Chicago.

National District Heating Association: Annual convention, June 26-28, Hotel Sherman, Chicago. Secretary, D. L. Gaskill, 603 Broadway, Greenville, Ohio.

Heating and Piping Contractors National Association: Annual convention, July 25-28, Chicago. Secretary, J. C. Fitts, 50 Union Square, New York City.

American Gas Association: Annual convention, September 25-29, Chicago. Headquarters Office, 420 Lexington Ave., New York City.

Recent Trade Literature

Ash-Handling Equipment: Hydro-Ash Corporation, 115 S. Dearborn St., Chicago. 14-p. booklet giving a general description of an ash-sluicing system consisting of a sealed ash-pit hopper from which ash is sluiced by high-velocity water jets into an enclosed trench; for plants having coal consumption of 50 tons per day or over; photos and diagrams.

Boiler Feed Control: The Plouff Corporation, Boston, Mass. 4-p. pamphlet reporting results of tests on battery of six gas-fired boilers with and without automatic feedwater regulation.

Hoover Dam: The Babcock & Wilcox Company, 85 Liberty St., New York City. 16-p. booklet describing this project and particularly the 30-ft. diameter fusion-welded plate steel pipes for the tunnels; maps, photos, diagrams.

Meters: The Foxboro Company, Foxboro, Mass. 8-p. bulletin on bell-type meters for low-pressure gas flow measurement; principle of operation, where to use, construction features, specifications; photos and diagrams.

Motor-Reduction Units: Westinghouse Electric & Manufacturing Company, Nuttall Works, Pittsburgh, Pa. 8-p. bulletin on single- and double-reduction gear motors consisting of external-type speed reducer combined with standard motor; ½ to 75 hp, 15 to 1550 rpm; applications, features, photos and diagrams. Also 4-p. pamphlet describing multi-speed gear motors with four instant speed changes; tables of hp rating and speed tables for motors from ½ to 15 hp ratings.

Motor-Reduction Units: Allis-Chalmers Manufacturing Company, Milwaukee, Wis. 4-p. bulletin describing self contained speed reducers with standard speeds at power take-off from 3.02 to 350 rpm, 1 to 50 hp; ratings and speeds; photos and diagrams.

Pipe-Threading Equipment: The Oster Manufacturing Company—Williams Tool Corporation, Cleveland, Ohio. Check sheets for making systematic survey of threading equipment.

Pumps: Worthington Pump and Machinery Corporation, 2 Park Ave., New York City. Data sheet on horizontal single power pumps designed for very viscous materials such as magma in sugar mills, heated soap, grease fats and similar liquids which will flow by gravity; ratings and dimensions; photos and diagrams.

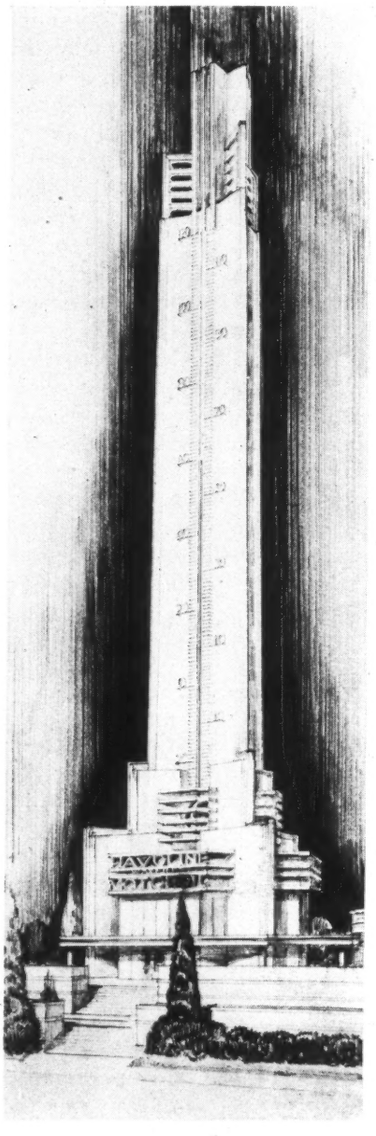
Recording Thermometers: The Foxboro Company, Foxboro, Mass. 48 p. catalog of recording thermometers, including descriptions of several new instruments, a new section on bulbs, and complete tables of recorder charts and typical chart sections. Among the new instruments are a recording thermometer so designed that temperatures surrounding the case and tubing do not affect its accuracy, a portable temperature recorder, and a new controller with rotating or commutator-type contacts; photos and diagrams.

Unit Pulverizers: The Strong-Scott Mfg. Co., Minneapolis, Minn. 32 p. booklet of photos and result-reports on representative installations of self-contained direct-connected pulverizers for firing boilers, stills, kilns and furnaces. Also 4-p. pamphlet illustrating and describing principle of operation.

200-Ft. Thermometer

A 200-ft high thermometer which will indicate the outdoor temperature at all times will house the oil-refining exhibit of the Indian Refining Company at A Century of Progress, Chicago's world's fair, next summer. Ground has been broken for the foundations of the steel frame for this monument to climate conceived by Chester Foust and Alphonse Iannelli.

The "mercury column" will consist of neon tubes electrically actuated by a master thermometer. The numerals on the three faces will be 10 ft high and will be visible day and night from all parts of the exposition grounds. Ten miles of wire, 3,000 feet of gas-filled neon tubing and 60 tons of steel will be required in the construction.



This 200-ft high exhibit building in the form of a huge thermometer will show visitors to A Century of Progress the actual outdoor temperature at all times. Neon tubes indicating the temperature will be electrically actuated by a master thermometer

Heating·Piping
and Air Conditioning

American Society of Heating and Ventilating Engineers JOURNAL SECTION

APRIL 1933

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Fundamental Principles in the Design of Dry Air Filters

By Otto Wechsberg*, Worcester, Mass. *(MEMBER)*

THERE are various kinds of filtering materials for which different advantages are claimed, such as low cost, easy replacement, high dust separating efficiency, low resistance, etc. Generally, the preponderance of one advantage excludes or weakens all or some of the other necessary requirements.

Problem Analyzed

In order to illustrate the principles involved in the design of an air filter, a definite problem will be analyzed. Assume that the specification calls for a dry air filter 20 in. x 20 in. with a capacity of 800 cfm at a resistance of ¼ in.

For the tests described in subsequent paragraphs an all-wool felt weighing approximately 16 oz to the yard of 72 in. width was used. Through it will pass 73 cfm of air per square foot flowing in a direction vertical to its surface, with a resistance of ¼ in. To design a filter of the specifications stated in the preceding paragraph (800 cfm at ¼ in. resistance) it would be necessary to provide 11 sq ft of filter medium within the filter unit of 20 in. x 20 in., were it not that the capacity per square foot of filter medium decreases if the air flows parallel with or at a slight angle to the surface of the filter medium. It will be necessary, therefore, to provide a considerably larger filter area within the limited dimensions of the unit filter.

In analyzing a problem of this nature, a clear understanding of velocities and resistance is important. Take, for instance, an air duct of 20 in. x 20 in. inside dimensions, the area of which is approximately 2.75 sq ft, and assume that through it flows air at the rate of 73 cfm per square foot; in other words, a total of 200 cfm. The velocity of the air flow will be 73 fpm.

If a plate is placed into this duct at right angles to the direction of air flow, with an opening having a diameter of 4¼ in., it will cause a resistance of ¼ in.; in other words, ¼ in. pressure difference is necessary to force 200 cfm through an orifice of 4¼ in. diameter (14.4 sq in. area). The velocity of the air through the duct will be 73 fpm, but through the orifice itself, 2,000 fpm.

If a plate with a large number of openings is used, the combined area of which is equal to the area of the orifice, for instance, a screen of proper mesh, the resistance will be the same, provided the plate is sufficiently thin. The velocity through the many openings will be again 2,000 fpm as long as the combined areas are equivalent to the area of an orifice of 4¼ in. diameter. Furthermore, if a sheet of the filter medium (all-wool felt) is placed in the air duct, the resistance to the flow of 200 cfm of air (73 cfm per square foot) will be ¼ in. which indicates that the combined area of the countless small openings through the filter medium will again be equivalent to the area of the orifice of 4¼ in. diameter. The average velocity of the air passing through the small openings in the filter medium will again be 2000 fpm.

These figures of combined area and velocity through the filter medium are not entirely correct. As long as the ratio of the diameter of the opening to the thickness of the plate is high, the friction of the air against the side walls of the orifice can be disregarded. The length of the minute air passages through the filter medium, however, is many times their diameter and, therefore, to maintain the resistance at ¼ in., the combined area of all the minute openings for the passage of air through the filter medium will have to be considerably larger than the area of the equivalent orifice. In any event, the velocity of the air flowing through these minute air passages of the filter medium will be considerably higher than the velocity of the air in the duct.

From the foregoing discussion it is clear that *the highest velocity of flow the air reaches anywhere on its passage through the filter unit is through the filter medium itself*. The linear velocity of the air through the *filter* (not through the filter medium) is understood to be the velocity the air would have when flowing through an open duct of an area equivalent to the face area of the filter. The linear velocity through the *filter medium* in an impingement type air filter is also taken as the velocity through a duct of area equivalent to the face area of the filter. This is quite logical because the filter medium is arranged in the shape of a plate vertical to the air flow and has the same face area as the filter cell.

With a dry air filter, conditions are, however, entirely different because the filter medium has an area which is a multiple of the face area of the filter cell. The so-called linear velocity through the filter medium, a grossly misleading term used in many specifications, has here no other value than to indicate the velocity the air would have if it would flow through an open duct with an area equivalent to the number of square feet of filter medium used in the filter unit. The fact remains that nowhere in the filter unit is the air velocity as low as this *linear*

*President and General Manager, Coppus Engrg. Corp., Worcester, Mass.

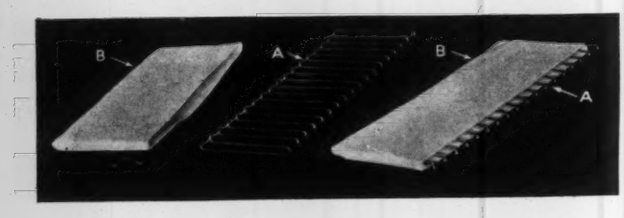


Fig. 1 (above)—Wire loops and pocket used in tests

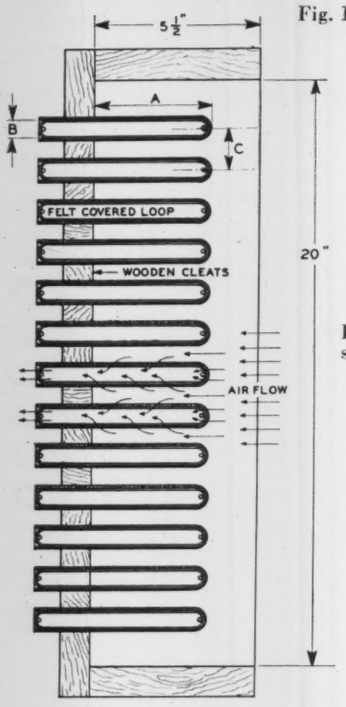


Fig. 2—Section through assembly of complete test unit

velocity specifies, and that it is the highest through the filter medium.

After the filter medium is chosen and the amount of air passing through it per square foot at ¼ in. resistance is established, the next and most important step in the design of a filter is the proper arrangement of the filter medium within the limited space of the filter unit. To fully understand the principle involved, it is necessary to differentiate between the resistance encountered by the air in its flow through the filter medium proper and the resistance through the filter, which latter is materially affected by its design, *i. e.* the arrangement of the filter pockets, the nature of support for the filter medium, the unrestricted passage of the air before reaching the filter medium and after passing through it, etc. To ascertain the most favorable design, extensive tests were conducted which are described in the following paragraphs.

Tests Conducted

To test the results with filter pockets of different widths, depths and spacings, a number of sets of wire loops of different widths were used. One of these loops is shown in Fig. 1, indicated by *A*. Felt pockets (*B* in Fig. 1), open at one end, were drawn over these individual wire loops and then mounted in a wooden box having inside dimensions of 20 in. x 20 in. The different spacings of these felt covered wire loops were accomplished by inserting between them wooden cleats of varying widths. The assembly of such a complete test unit is shown in Figs. 2 and 3.

This arrangement made it possible to conduct tests with differently spaced felt-covered loops of various widths, changing the depth of the filter pockets for every individual test by pulling out the wire covered loops between the wooden cleats. In doing so, the effective area of the filter medium was increased.

The surprising result was that on all the tests with wire loops of different widths and different spacings the capacity of the test unit increased up to a depth of the pockets of approximately 4½ in. Beyond this depth the capacity was reduced, notwithstanding that the greater depth provided a larger filter area. The results of these tests are shown in Fig. 4.

The table at the bottom of Fig. 4 gives the number of felt covered loops used, the width of the loops (Dimension *B*, Fig. 2) and their spacing (Dimension *C*, Fig. 2), for every one of the six test curves. On all six test curves identical marks indicate the depth of the filter pockets (Dimension *A*, Fig. 2) for the respective points of the curves.

Curve 4 of Fig. 4, for instance, shows the results of an assembly of 18 felt covered wire loops ⅜ in. wide and spaced 1 in. apart from center to center of loops. A depth of the filter pockets of 3⅞ in. gives a filter area of 17½ sq ft, and the capacity at ¼ in. resistance is 775 cfm. If the depth of the filter pockets is increased to 4½ in., the filter area is increased to 20.3 sq ft and the capacity to 800 cfm. A further increase of the depth of the filter pockets to 5 in. increases the filter area to 22.75 sq ft, but the capacity at ¼ in. resistance drops down again to 775 cfm.

A comparison of the test data of any two of the curves gives some interesting figures. Curve 1, for instance, represents the arrangement with 16 felt covered wire loops, ½ in. wide and spaced 1⅛ in. apart.

The depth of the filter pockets, adjusted to 3⅛ in. gives a filter area of 12.7 sq ft. The capacity of the filter at ¼ in. resistance is 700 cfm. On the other hand,

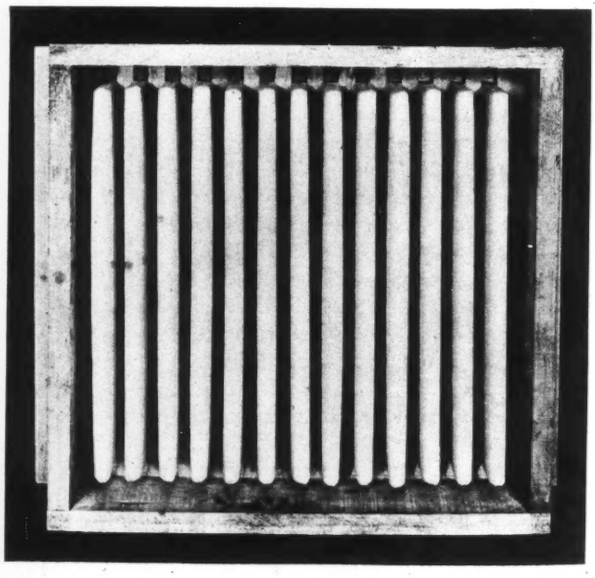


Fig. 3—Photograph of test unit

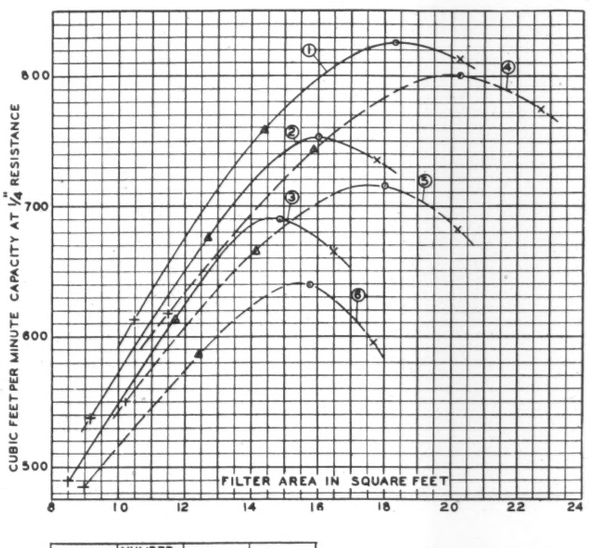
Curve 5 is plotted for an arrangement with 16 loops ⅜ in. wide and spaced 1⅛ in. apart. A depth of 4 in. of the filter pockets gives a filter area of 16 sq ft and the capacity at ¼ in. resistance is again 700 cfm.

Increase of Filter Area

It is, therefore, evident that beyond a certain depth of filter pockets an addition of filter area ceases to be of any advantage. It is logical to assume that with a larger filter area the resistance of the air passing through the filter medium is reduced. On the other hand, the additional depth of the filter pockets increases the resistance of the air in reaching the filter medium and this additional resistance finally becomes so high that it offsets the theoretical advantage of providing a larger filter area.

The surprising result of the tests is that the capacity of the filter for a given resistance is not only not increased with increasing depth of the filter pockets beyond a definite dimension, but actually reduced. The reason for this phenomenon is that the resistance of the air flowing inside of the felt covered loops (after passing through the filter medium) is increased with the depth of the pockets. In other words, the vacuum inside of the loops which draws the air through the filter medium is reduced and with it the rate of flow of the air per square foot of filter area.

This contention is borne out by a comparison of Curves 1 and 6. For both curves the capacity at ¼ in. resistance reaches a maximum with 4½ in. depth of the filter pockets. For Curve 1, the capacity is only slightly reduced (1½ per cent) if the depth of the pockets increases to 5 in., whereas for Curve 6, the capacity is reduced approximately 7 per cent.



CURVE	NUMBER OF WIRE LOOPS	B	C
1	16	½	1⅛
2	14	½	1¼
3	13	½	1⅜
4	18	⅜	1
5	16	⅜	1⅛
6	14	⅜	1¼

ON ALL SIX CURVES THE DEPTH OF THE FILTER POCKETS (DIMENSION A) IS INDICATED BY IDENTICAL MARKS:
+ INDICATES A = 2½
△ INDICATES A = 3½
○ INDICATES A = 4½
× INDICATES A = 5
DIMENSIONS A, B AND C REFER TO FIG. 2.

Fig. 4—Results of tests

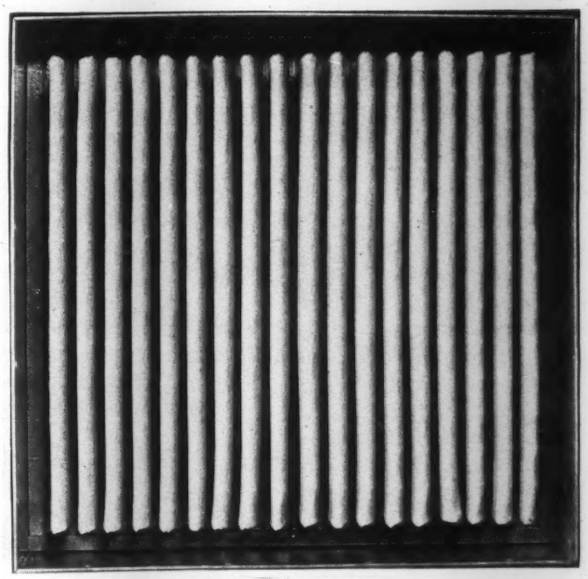


Fig. 5—Unit filter—air intake side

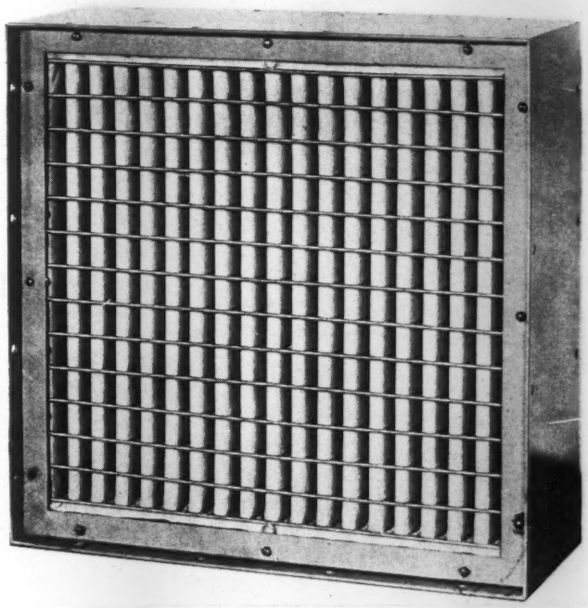


Fig. 6—Unit filter—clean air side

Curve 1 is plotted for a test arrangement with 16 loops of ½ in. inside width and 1⅛ in. spacing, Curve 6 for an arrangement with 14 loops, ⅜ in. wide and 1¼ in. spacing between centers of loops. In the former case an increased length of the loops does not increase the resistance of the air flow inside of the loops as much as in the latter case where the loops are only ⅜ in wide.

The important thing in the design of a dry air filter is, therefore, not the amount of filter cloth crowded into the limited dimensions of the filter cell, but rather the most efficient arrangement of the filter pockets. In other words, the design of the filter has to be such that

the air encounters the least possible resistance before reaching the filter medium, and after passing through it. The linear velocity is only an indication of the amount of filter cloth contained in the filter unit, but has no influence on the capacity of the filter for a given resistance beyond the point representing the most efficient design of the filter.

It will be noted from Figs. 5 and 6 how the filter felt is stretched tautly over the wire frame in order to allow on the air intake side, as well as on the clean air side, unrestricted flow of the air to the filter medium and again after passing through it. In a correctly designed filter of this type, the arrangement of the filter pockets should be such as to add the minimum amount of resistance to the unavoidable resistance of the air when passing through the filter medium itself.

Summary and Conclusion

In a dry air filter the highest velocity the air reaches anywhere on its passage through the filter cell, is the velocity through the filter medium itself, which is evident by the fact that pressure is necessary to force the air through the filter medium. The important thing in the design of a dry air filter is not the amount of filter cloth crowded into the limited dimensions of the filter cell, but rather the most efficient arrangement of the filter pockets.

The Electronic Recorder*

By H. L. Bernarde and L. J. Lunas,† Pittsburgh, Pa.

IT takes a great deal more power to move a pen across paper than is available in the coils or circuits of ordinary indicating instruments. For certain measurements, only the *high sensitive* type of instruments are applicable. The friction of a pen across paper is from a hundred to a thousand times as great as the friction in jewelled movement bearings. Thus indicating instruments of the microampere class have been available for some time, in contrast to which conventional recorders have been of the milliampere class as exemplified in direct current d'Arsonval type instruments.

To record low energy values accurately, it is essential that the recorder consume negligible power in comparison to the value being recorded. To this end, schemes of recording making use of the relay principle have been in use both here and abroad, but in every case relay type recorders of the mechanical type have definite limitations in speed, power consumption and sensitivity. Contacts in conventional type recorders limit sensitivity by requiring in themselves considerable pressure to operate.

The radio receiver picks up a microscopic amount of energy from the air and amplifies it to concert volume. Would not electronic means therefore afford a similar solution to the problem of recording low energy values? This led to a thorough investigation of the various electronic methods which would accomplish the result.

One of the first methods tried was a liquid potentiometer arrangement consisting of a bridge type circuit in which a high torque recording system followed the low energy measuring element, the contact between the two systems being a liquid potentiometer having negligible contact friction.

Another method which showed promise was a modulated light scheme in which the direction and operation of a high torque pen driving mechanism was controlled by a photocell which was illuminated by either a steady light which was interrupted by a rotating or vibrating shutter or by means of a flickering neon lamp.

Several balanced inductance bridge arrangements were investigated in which one arm of the bridge was an A-C instrument in the measuring circuit. Any change in the measured value unbalanced the bridge and the resulting difference in potential was used to drive a high torque pen driving element by a relay method. This was limited to alternating current measurements.

All these arrangements had certain limitations and disadvantages in that they were either limited to A-C measurements or made use of photocells, optical systems or contacts which require maintenance or have certain limitations as regards ambient temperature.

This general investigation advanced to the point of finding a means, free from all these disadvantages and limitations, which seems sufficiently complete and flexible to answer the requirements. It promised a practical method of obtaining accurate record charts from the action of a simple indicating instrument. It depends upon the use of an additional coil mounted on the moving element of the measuring instrument. This coil does not add any appreciable work for the measuring element to perform, therefore, the accuracy or the torque requirement is not changed. This coil is used as a detecting or pilot coil and is placed in the field of a stationary alternating current electro-magnet. The object of the pilot is to detect the position of the measuring element with respect to the electro-magnet. A duplicate of this coil is mounted on the recording mechanism and arranged to operate in the field of a similar electro-magnet excited from the same alternating current source. The relative position of these pilot coils is compared and controlled by their relative action on an auxiliary circuit. The current in this auxiliary circuit is amplified to give power sufficient to drive a high torque pen driving element.

The electronic recorder consists essentially of the following parts:

a. The primary, or measuring element which may be any usual type indicating instrument mechanism.

b. The pilot element attached to the measuring element.

c. The pilot element at the pen mechanism.

d. The motor element for driving the recording pen and for carrying the second pilot element coil.

e. An amplifier for furnishing reversible driving power to the pen motor.

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Comfort Air Conditioning*

Cooling Coil or Surface Cooling Method

By **Claude A. Bulkeley† *(Member)***

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ONE of the first things learned in chemistry is that water is our most universal solvent. In other words, the most abundant and common liquid would dissolve more substances than anything else.

Coming to gases, the most universally present gas is air—a mixture of oxygen and nitrogen. Because of its omnipresence, air is the gas most frequently used as a diluent for other gases. In fact, one of the problems in industry is to eliminate its presence when not wanted. As an example, all air must be eliminated in the feed water of large central power stations to prevent corrosion of the boilers.

Air and water being so abundantly present everywhere in nature, it is not strange that they both enter into almost all problems of modern civilization. What might be called gas engineering is therefore a very wide field.

Gas engineering in its broad aspects includes many subdivisions; as an example combustion in its varied applications from oxidation of elements in process of manufacture, to the generation of steam in large central power plants.

In fact, almost all of the elements of nature, at some point in the processes of manufacture, and under the influence of heat, become volatile and thus generate gases which must be handled and recovered or disposed of by the gas engineer and usually air—being the most universally present gas—enters into this problem. So perhaps a somewhat narrower scope for the gas engineer might be that of the air engineer.

The drying of most materials, in process of manufacture, calls for the removal of liquids used in their preparation, which include water as well as many varied solvents. Where these diluents or solvents are of commercial value their recovery enters into the problem and this is known as solvent recovery. This, alone, is wide and varied in methods of application.

Air also is often used as a carrier for the conveyance of all kinds of materials varying from dust, blocks of wood, to sizable chunks of lead and brickbats.

A still further sub-division of air engineering is that of air conditioning.

Naturally air conditioning is thought of as the most prominent field of activity, because of its applications to industry and to the popular field of human comfort. Industrial air conditioning has been extensively in use for the past quarter of a century and yet had not human comfort been an incidental concomitant of air conditioning in industry, the public would never have had opportunity to experience and want the added comfort and health resulting from the proper conditioning of the air in which we move and have our being.

As an outgrowth of industrial air conditioning many of its applications to comfort have made use of the same method of air treatment, viz., the passing of the air through a chamber copiously filled with finely divided water particles sprayed into the air current through atomizing nozzles.

If the temperature of this atomized water is controlled by the application of heat or refrigeration, then the amount of moisture or water vapor contained in the leaving air is dependent on its temperature, and can be maintained within narrow limits of variation.

Comfort air conditioning as generally known provides not only pure air with regard to the presence of foreign particles or gases, but also the definite control of the amount of moisture in the air within certain rather narrow limits as to temperature. How narrow these limits of temperature are may be realized if we stop to think that from absolute zero to the temperature used in the electric oven, a range of 5000 to 6000 deg, indoor conditions for human comfort must be kept within a range of 15 deg or between 70 and 85 deg. The temperature within this range that is the most comfortable depends upon two things—the amount of moisture in the air and the relative outdoor conditions. When cooling is desired as in summer it goes without saying that it should feel cooler on entering from the outside. This may occur even though the inside may be several degrees warmer temperature than the outside. For example, with 70 deg and 90 per cent relative humidity outside and with 75 deg and 50 per cent inside, it will feel cooler inside, because of the lower moisture content of the air. The real reason is because 70 deg and 90 per cent air contains about 4 Btu more per pound of air than when at 75 deg and 50 per cent.

If the air is kept at or below 50 per cent relative humidity, an inside summer minimum temperature of 75 deg should be generally satisfactory.

On the other hand, when the outside temperature is above 90 deg, 75 is too cool by comparison, and too much shock occurs when passing from inside to outside.

The question may be asked, why are we comfortable in winter with a minimum of 70 deg and 30 to 40 per cent relative humidity and will be equally comfortable in summer with a higher temperature and relative humidity. This is due to seasonal adaptation of the body to meet outside conditions.

Much popular criticism has been made with regard to comfort cooling that it was too cold or chilly inside. Such

*One of a series of papers presented at the Symposium on Refrigeration, New York Chapter, January 1933.

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criticism has been made, not so much because of too low a temperature inside, but because of too high a relative humidity. Entering from the warm outside into a cooler inside temperature in summer is somewhat analogous to going from the warm inside temperature into the cooler outside, in winter.

All will agree that a damp outside condition feels chillier at say 40 deg than several degrees cooler if it is dry—there is something invigorating about a dry cold that eliminates the chilly feeling. This same thing applies to comfort cooling in summer.

With the same total heat in the air inside, but with the dry bulb temperature actually higher and less moisture in the air it will be more comfortable within certain limits—for example with 90 deg dry bulb and 75 deg wet bulb outside and an inside wet bulb of 67 deg (a difference in total heat content per pound of air of nearly 7 Btu) it will be much more comfortable and less shock will occur in passing from inside to outside if the inside temperature is 80 with 50 per cent relative humidity than if it is 75 and 65 per cent although in both cases the wet bulb and total heat content of the air are the same. Under the latter condition of higher relative humidity, perspiration will remain on the skin and the body is in poor condition to go into the oppressive outside. If the inside is to remain at 75 deg the relative humidity should be not over 50 per cent for then, while cool, it will be more invigorating, the skin will be dry and the body in good condition to adjust itself to the outside and it will not feel so chilly for the reason cited in the winter comparison.

In summary it might be said that in this climate, the conditions maintained inside for comfort cooling should be about 10 deg below the outside with an inside minimum of 75 deg and with a relative humidity of not over 50 per cent and it may be as low as 40 per cent and still be well within both the comfort and health zone. To meet these conditions under varying conditions of outside temperature and inside heat load, the air washer is not as well suited as the surface cooling coil method.

Briefly described, the cooling coil or surface cooling scheme consists in passing the air to be conditioned through cooling coils or surface in a manner similar to that for heating in the winter, with this difference,—that water is pumped and circulated through the coils.

This cold circulated water should be furnished at approximately 35 or 40 deg and circulated at a differential of not more than 4 to 6 deg. This water is pumped in a closed circuit over and over in manner similar to a forced hot-water heating system. Obviously this water can be cooled or refrigerated by the use of ice, steam or mechanical refrigeration. Since with mechanical refrigeration the water is or should be cooled in a shell and tube cooler, any refrigerant can be used with equal safety such as CO_2, ammonia, F12, or any other and since water can be economically pumped through pipe lines for considerable distance, the refrigerating plant can be isolated at some distance from the conditioning or cooling coil equipment. For example, ammonia could never get into the air stream unless a simultaneous leak occurred in the shell and tube cooler and in the cooling coils. If the coils have been tested under 500 lb hydrostatic test, safety is still further assured. The amount of cooling done to meet varying load conditions can be done by using face and bypass dampers on the coils as has been done in heating since Tige was a pup; or, the flow of water through the coils can be varied. If the flow through coils is varied, the normal flow through the pump and cooler can be maintained by use of bypass valve, or a relief valve on the pump, or the entire flow can be throttled as required. It makes no difference in the operation of the cooling coils so long as the flow through the coils is varied to meet the amount of cooling required.

Refinements in design that have much to do with the successful operation of a surface cooling coil system are many:

First—The change in position of dampers or amount of flow of water through the coils should be very gradual even intermediate in position of dampers or valves. This, of course, calls for automatic temperature control.

Second—The initial temperature of the water should be kept constant, the refrigerating load varying as the rise in water temperature which will be proportional to the cooling load. This is necessary in order that the relative humidity be kept down.

Third—The flow of water through the coils should be countercurrent with relation to directional flow of the air and with at least four passes for the water flow. This latter means that with the same initial temperature of water the last contact between air and coil will have a temperature difference the same as with full flow of water through the coil and while less cooling of the air will occur it will be properly dehumidified.

Fourth—The coils as well as the casing should be of aluminum. These coils and the casing are wringing wet most of the time. Being wet, but not flooded as in an air washer, makes them very susceptible to the corrosive action of urban air which always contains traces of sulphur dioxide and sulphuric acid. Minute traces of acid mixed with air and distilled water (which is the composition of the condensate) is far more corrosive than a strong acid mixture. Other metals that have been used for either the coils or casing have failed from corrosion in from one to three years. This is the result of experience, not theory. So far as is known, the life of aluminum, under these conditions, is indefinite as coils that have been in this character of service for over five years show no indication of corrosion.

Fifth—The rate of water flow, in feet per second, through the coils, has everything to do with the proper relationship maintained between amount of cooling and the amount of dehumidification accomplished while at the same time the flow itself is varied to meet the changes in amount of cooling required.

If this relationship be maintained between face velocity of air flow through the coil, proper counter-flow of water and proper spacing between primary and extended fin surfaces, the air will always be dehumidified the required amount to maintain an inside relative humidity of not over 50 per cent even when the amount of cooling is reduced to the minimum and without reheating with steam, when cooling is required. In other words, when less cooling is required, a much larger percentage of the heat is extracted from the air by dehumidification.

To make it a little clearer it might be said that—under varying conditions of outside temperature and inside heat load to be adsorbed, the air seldom leaves the coils at higher than 80 per cent nor lower than 70 per cent relative humidity. As more cooling is done the air leaves at a lower temperature and a higher relative humidity. Thus the relative humidity inside always tends to remain constant and in actual wide changing operating conditions does not vary more than 10 per cent or between 40 and 50 per cent.

Sixth—The entire plant should be 100 per cent automatic in

operation whether ice, steam or mechanical refrigeration is used. The amount of refrigeration should be thermostatically controlled by the water temperature and automatically go entirely off if the circulating pump stops operating either accidentally or is automatically shut down as it should be by the controlling thermostat in the room when no cooling is required. The entire system should, of course, automatically go back into operation as required to maintain the proper room conditions. The automatic starting and stopping of the entire cooling plant (except the fan) should take place within one degree change in room temperature.

In summation it might be said that three important factors are required for successful surface coil cooling. They are:

1. Properly designed and installed coils
2. Sufficient refrigeration and
3. A very efficient control system

One is as important as the other. Comfort surface cooling could of course not be done at all without coils and refrigeration and yet both of these might be adequate and if the control did not function 100 per cent all the time, the installation would be a failure. Accurate effective control for comfort cooling is immeasurably more important than it is for heating during the winter. In fact, it is an absolute necessity for successful results.

The statement was made that the air washer, as compared to the cooling coil method, was not as well suited for comfort cooling. The following comparison between the two methods is therefore in order:

1—Let us first dispose of the air washer as a cleansing medium. It never did remove oily and greasy dust particles for the reason that they are not only insoluble in water but do not mix with it. Filters are necessary whether the air washer or coil method be used.

2—The width and height on the coil installation is about the same as for the air washer but the length in direction of air travel need not be over 20 in. instead of 9 ft as with the washer and even if humidifying equipment be added to the coils, the total over-all length is not over half that of the washer. This makes it possible to install cooling in connection with present ventilating systems where an air washer could not be installed for lack of space. Even on new installations this saving in space is an advantage.

3—The life of the air washer is limited and repairs and maintenance high. The eliminators on an air washer have been known to require renewal within a year and the whole installation will last only 5 to 8 years unless made of non-ferrous metal.

4—The power requirement for water pumpage is about 25 per cent less for the coil than the air washer.

5—The washer, if efficient, must cool the air to saturation which means 20 deg or more below room temperature to maintain 50 per cent or less relative humidity. This necessitates either heating the air after cooling or bypassing a portion of the air. Where all fresh air is required, obviously none of the air should be bypassed. This is all because saturated air 20 deg or more below room temperature cannot be discharged into a room without objectionable drafts or going to extra precautions to avoid them.

Properly installed cooling coils dehumidify the air to a dew-point 5 to 10 deg below the temperature to which it is cooled, hence all the air can be passed through the coils at all times and bypass control is not required.

6—As stated, the washer cools to saturation, while the coils do not. The coils are automatically self-adjusting with regard to cooling and dehumidifying. As less cooling is required with drop in heat load to be absorbed, the air leaves the coils drier and prevents the relative humidity in the room rising about 50 per cent.

7—If an equally efficient system of cooling is installed, the coil method, while requiring the same maximum demand in refrigeration, if anything, will be more economical in its use.

8—If the refrigeration fails or at any time is inadequate, the cause may be that the air washer, will not dehumidify—it may add moisture to the air at the same time it cools, and to so lose control of the relative humidity on a cooling job is far worse than to have temperature rise. The cooling coil cannot add moisture to the air and as long as the coils are cooler than the air some cooling at least will take place.

9—With the cooling coil method there is no chance for the refrigerant to get in the air stream hence ammonia, the simplest of refrigerants, can be safely used, with mechanical refrigeration.

10—In a properly designed washer or cooling coil installation the cost of installation is about the same—if anything in favor of the coils.

Comparative summation indicates that filters are required with either system; that the surface cooling requires less space; repairs, maintenance and cost of operation are lower; life of the equipment is longer; method of operation simpler; any refrigerant can be used safely, and results obtained are therefore better at about the same cost for installation.

Society Code Adopted for Testing Standard Insulating Board

The commercial standard for fiber insulating board was developed by a group of manufacturers of this product who were desirous of establishing a nationally recognized quality standard for the guidance of the architect, builder and prospective home owner.

The commercial standard is a minimum specification embodying the important characteristics of a satisfactory insulating board, chief among which is maximum thermal conductivity set at 0.36 Btu per hour per square foot, per degree Fahrenheit, per inch thickness. Since this class of board is used structurally as well as for its insulating value, strength is an important characteristic and therefore tensile and deflection requirements are included in the specification. Another essential is the ability of the material to make a tenacious bond with plaster, and to assure this it must possess a minimum plaster adhesion of 600 lb per square foot. Water absorption, lineal expansion and standard stock sizes are the other items included in the commercial standard.

The thermal conductivity tests are made in accordance with Part II, Conductivity of Homogeneous Materials of the Standard Test Code for Heat Transmission Through Walls, as adopted by the American Society of Heating and Ventilating Engineers. Methods for the other tests are also given.

The printed edition of the commercial standard includes a brief report of the general conference and the membership of a representative standing committee which is charged with the revision of the standard when such action appears necessary. A list of the official acceptors of the commercial standard is also included.

The commercial standard became effective for new production September 15, 1932, and a pamphlet entitled, Fiber Insulating Board, has been issued by the Bureau of Standards and may be obtained from the Superintendent of Documents, Government Printing Office, Washington, D. C., at small cost.

Where Is The Perspiration Line?

By **A. E. Beals, Norwich, N. Y.**
NON-MEMBER

STATISTICS show that, from the standpoint of the conservation of health, a fairly high moisture content in the atmosphere is desirable. It has also been observed that humidity has a considerable bearing upon the working capacity of men but that neither a too dry nor a too moist condition of the atmosphere is beneficial. It is stated that the best working results are obtained with an inside relative humidity of about 60 per cent when the temperature ranges between 65 and 70 F.

From the foregoing, it would seem that, with people at rest or slightly active, as in theaters, the relative humidity could be somewhat higher than 60 per cent at 70 F and still produce an effect of comparative comfort. Would not the ideal condition to be maintained in an auditorium follow approximately the *perspiration line* if it could be located upon a psychrometric chart?

Meaning of Perspiration Line

By perspiration line is not meant the point of no perspiration because there must be a more or less amount always present, depending upon the surrounding temperature. It is the cooling effect of the latent heat of evaporation of the perspiration which makes up the difference between the total heat, constantly generated in the body, and that carried away by radiation and convection. The heat radiated from the body is a function of the difference between the body temperature and that of the surrounding atmosphere. The higher the surrounding temperature, the less the amount of heat radiated and consequently the greater the supply of perspiration to be evaporated.

The A. S. H. V. E. Research Laboratory has determined the variation in the amount of heat lost by radiation and by evaporation for different conditions of dry-bulb temperatures. Fig. 1 shows graphically the results of their findings in percentages of total heat carried away by each method for different degrees of surrounding temperatures.

Fig. 2 shows the weight, in grains, of perspiration per hour to be evaporated in conformity with the values taken from Fig. 1. The quantities shown in Fig. 2 were determined on the basis that the total heat to be dissipated amounts to 420 Btu per hour for an adult person. As an example assume a temperature of 80 F. The heat carried away by radiation is 55 per cent and by evaporation is 45 per cent of 420 Btu. Therefore, the grains of moisture required amount to $\frac{0.45 \times 420 \times 7000}{1046.7}$ = 1265 per hour. Similarly it is found that the amount of perspiration at 70 F will be 680 grains per hour and at 90 F, 2050 grains per hour.

Evidently, then, the perspiration line could not mean the point of no evaporation, but that condition where perspiration is not present to the extent that it is felt or can be wiped away from the surface of the skin. In other words, it is that point where the condition of the atmosphere is such that whatever may be the temperature of the surroundings, the perspiration will be completely evaporated as fast as formed.

Considering again the foregoing example of 80 F, whatever the condition of relative humidity, there will be a constant exudation of perspiration amounting to 1265 grains per hour. If the relative humidity of the atmosphere is 100 per cent, there may be a slight degree of evaporation taking place, but it will not nearly keep pace with the accumulation of perspiration, with the consequent feeling of discomfort. On the other hand, if the relative humidity is very low, say around 30 per cent, evaporation will take place very rapidly, the surface of the skin will be free from an accumulation of moisture and there is likely to be a feeling of chilliness to the atmosphere although the perspiration will continue the same as before.

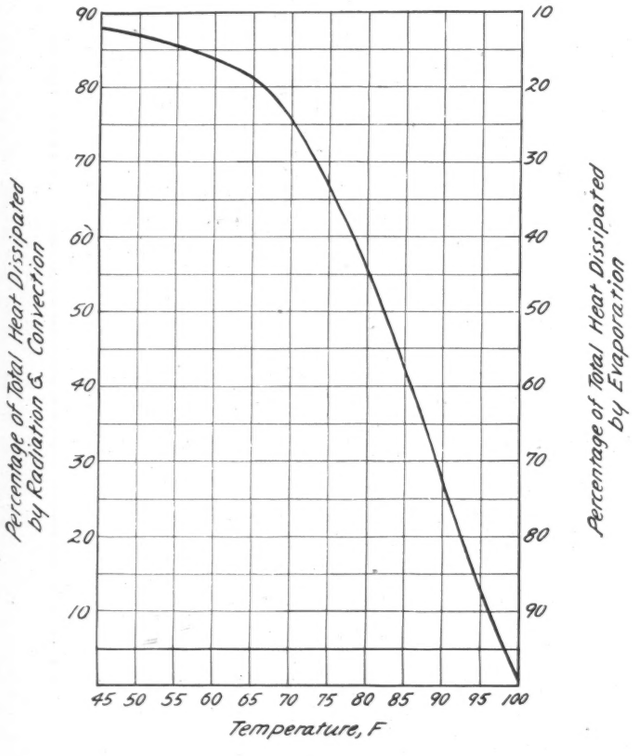


Fig. 1—Variation in amount of heat given off by the human body by radiation and convection

Rate of Evaporation

It has been stated that the rate of evaporation in still air is in direct proportion to the difference between the water tension and the tension of the vapor in the atmosphere, where the latent heat of evaporation is supplied from a source other than from the air itself. It would seem that this statement must be modified, at least to the extent of saying that the rate of evaporation of perspiration is some modified function of the difference between the water tension and the tension of the vapor in the atmosphere.

Let it be assumed that the atmospheric condition is such that the dry-bulb temperature is 70 F and the moisture content creates a vapor tension of 0.2326 lb pressure per square inch, absolute. Also let it be assumed that the rate of evaporation amounts to 690 grains per hour, which would keep the skin free from excess moisture at that temperature.

If the perspiration is carried away as fast as formed, its temperature upon reaching the surface of the body must be 98.6 F and its tension accordingly is 0.9075 lb per square inch. The difference in tension between the perspiration and the vapor in the atmosphere is 0.9075 — 0.2326 = 0.6749 lb per square inch. Therefore, if a difference of vapor tensions of 0.6749 lb per square inch is required to evaporate 690 grains per hour, it will require a difference of $\frac{0.6749}{690} \times 1265 = 1.236$ lb per square inch to evaporate 1265 grains per hour, this being the amount of perspiration introduced at 80 F. Since the tension of the water is only 0.9075 lb per square inch, the vapor tension in the atmosphere under this condition must be a negative quantity, which is an absurdity.

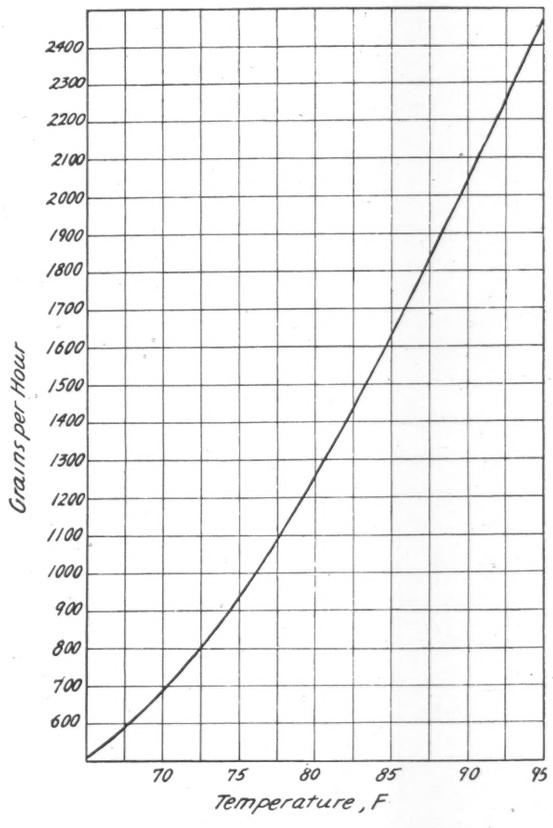


Fig. 2 — Perspiration given off by human body at various temperatures*

Approaching the problem from the other way, let it be assumed that the temperature is 80 F and the relative humidity is 30 per cent. The vapor tension of the atmosphere will then be 0.1515 lb per square inch and the difference in tensions will be 0.9075 — 0.1515 = 0.7560 lb per square inch. If, in this case, the evaporation amounts to 1265 grains per hour, the required difference in tension to evaporate 690 grains per hour at 70 deg will be $\frac{0.7560}{1265} \times 690 = 0.4120$ lb per square inch. Therefore, the air tension at 70 F may be as high as 0.9075 — 0.4120 = 0.4955 lb per square inch, which would bring the atmosphere up into the region of dense fog.

It is thus evident that there must be some modification of the assumption that the rate of evaporation of perspiration in still air is directly proportional to the difference between the tension of the water to be evaporated and the vapor tension in the atmosphere. It would seem that this rate is governed by some other factor.

Condition of Surrounding Atmosphere

Nature has provided means whereby the amount of perspiration is automatically regulated to suit the requirements and, at the same time, supplies the proper amount of heat to evaporate it. Thermodynamically, the heat adjustments of the body are balanced to provide a feeling of comfort, but the environment does not always cooperate to the best advantage. In other words, the condition of the surrounding atmosphere must be such that it can carry away and dissipate the heat rejected into it at the same rate at which it is generated at its source. If this rate is greater than the requirements, undue strain is put upon the nervous system in an effort to generate sufficient heat to supply the drain. On the other hand, if this rate is insufficient, undue strain is imposed upon the nervous system in an effort to prevent the body from becoming overheated.

The temperature of the surrounding atmosphere determines the amount of perspiration furnished for cooling purposes and also regulates the amount of heat available for its evaporation. The vapor content in the surrounding atmosphere determines the rate at which the environment can carry away the heat rejected into it from the body.

Now, since the amount or rate of flow of perspiration is automatically adjusted to the amount of heat available

* **EDITOR'S NOTE: The values for Fig. 2 have been calculated on the assumption that the total heat dissipated amounts to 420 Btu per hour for an adult person. It would not be necessary to calculate these values as they are given directly in Curve D, Fig. 7, p. 405, A. S. H. V. E. GUIDE 1932, based on data obtained by the A. S. H. V. E. Research Laboratory, Pittsburgh.**

Whereas the author has assumed a total heat dissipation of 420 Btu per hour for an adult, the results of the A. S. H. V. E. Laboratory shown on Curve D, Fig. 5, p. 403, A. S. H. V. E. GUIDE 1932 give 400 Btu per hour. The laboratory data are predicated upon what the U. S. Bureau of Standards recognizes as an average adult male.

for its evaporation, this heat in turn, being governed by the condition of the surrounding atmosphere, it is reasonable to suppose that the rate of evaporation must be governed by the capacity of the atmosphere to carry away the vapor from the surface of the moisture which produces it.

The capacity of the atmosphere for absorbing vapor is inversely proportional to its relative humidity. In other words, it is proportional to the difference between the total amount of vapor which it is capable of holding at the saturation point and that which it actually holds. If this hypothesis is correct, the absolute humidity of the atmosphere being known for a certain rate of evaporation at a given temperature, then the absolute humidity required at some other temperature and for another rate of evaporation may be calculated.

Referring to the previous example, the dry-bulb temperature is 70 F and the vapor tension is 0.2326 lb per square inch. The maximum tension at 70 F is 0.3626 lb per square inch, the difference between the actual tension and the maximum tension being 0.1300 lb. The rate of flow of perspiration at 70 F is 690 grains per hour and, assuming that evaporation takes place at the same rate under these conditions, there is required a difference of tension of $\frac{0.1300}{690} = 0.0001885$ lb per grain of moisture evaporated per hour.

Now if it is required to find the absolute humidity at which perspiration will be evaporated as fast as formed at 80 F and the rate of flow is 1265 grains per hour, the difference in tension between the maximum at 80 F and the required humidity will be $1265 \times 0.0001885 = 0.2380$ lb. The maximum tension at 80 F is 0.5050 lb per square inch, and therefore the required tension will be $0.5050 - 0.2380 = 0.2670$ lb per square inch. This tension corresponds to a vapor content of 80.7 grains per pound of air and a relative humidity of 53 per cent.

Table 1—Relation Between Vapor Pressure, Perspiration and Atmosphere at Various Dry-Bulb Temperatures

Temperature	Vapor Pressure at Saturation	Perspiration (Grs per Hr)	Vapor Pressure Difference	Vapor Pressure	Atmosphere		
					Relative Humidity Per Cent	Moisture Content Grs per Lb of Air	Dew-Point Temperature
60	0.2562	445	0.0838	0.1724	67.2	51.8	49.20
62	0.2749	466	0.0880	0.1869	68.0	56.2	51.30
64	0.2949	495	0.0933	0.2016	68.2	60.7	53.40
66	0.3161	540	0.1018	0.2143	67.8	64.6	55.10
68	0.3386	610	0.1150	0.2236	66.0	67.4	56.20
70	0.3626	690	0.1300	0.2326	64.2	70.1	57.30
72	0.3880	780	0.1470	0.2410	62.1	72.6	58.30
74	0.4148	880	0.1658	0.2490	60.0	75.0	59.15
76	0.4432	995	0.1875	0.2557	57.6	77.1	59.95
78	0.4735	1125	0.2120	0.2615	55.2	78.9	60.60
80	0.5050	1260	0.2375	0.2675	53.0	80.7	61.25
82	0.5390	1405	0.2645	0.2745	51.0	82.8	61.95
84	0.5750	1555	0.2930	0.2820	49.1	85.2	62.75
86	0.6130	1720	0.3240	0.2890	47.1	87.3	63.40
88	0.6540	1880	0.3540	0.3000	45.9	90.7	64.50
90	0.6960	2050	0.3860	0.3100	44.5	93.8	65.40

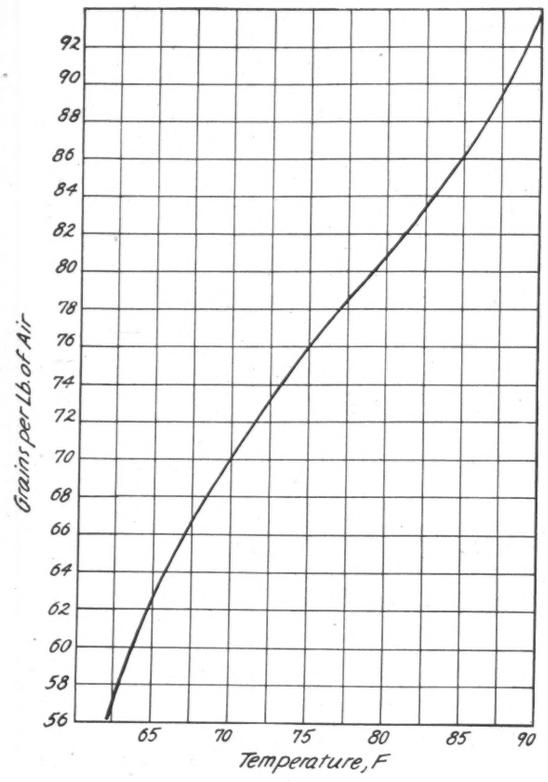


Fig. 3—Atmospheric moisture at perspiration point

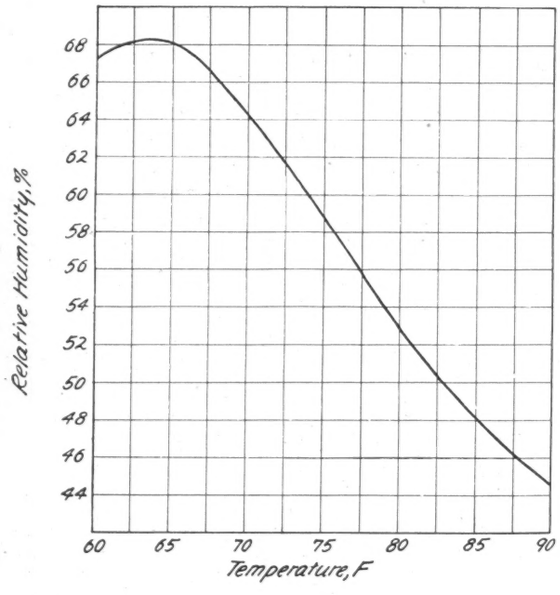


Fig. 4—Relative humidity at perspiration point

In the first instance, at 70 F the vapor content amounted to 70.1 grains per pound of air and a relative humidity of 64.2 per cent.

It will be noted that the vapor content per pound of air is greater but the relative humidity is less at 80 F than at 70 F, and the difference between the maximum tension and the actual tension at 80 F bears the same relation to the respective differences at 70 F as the rate

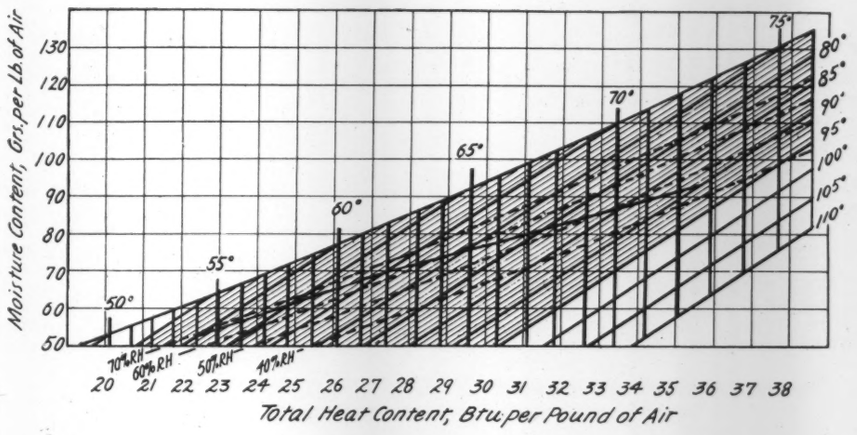


Fig. 5—Perspiration line

of flow of perspiration at 80 F bears to the rate of flow at 70 F.

If calculated on the basis that the rates of evaporation are directly proportional to the differences between the tension of the water and the tension of the vapor in the atmosphere, the moisture content at 80 F would require to be a negative quantity to correspond to the assumed conditions at 70 F. This is clearly shown by the first example worked out and is obviously an impossibility.

Table 1 shows the values of the different quantities for temperatures ranging from 60 F to 90 F. Fig. 3 shows the curve of moisture content in grains per pound of air for the perspiration line, based on the assumption that, at 74 F and 60 per cent relative humidity, the rate of evaporation just equals the rate of flow of perspiration. It will be noted that this curve has a gradually decreasing increment up to about 77½ F and a gradually increasing increment from that point up. The curve of Fig. 4 shows the relative humidities as based on the values of moisture content taken from Fig. 3. The maximum relative humidity allowable to meet the assumed conditions occurs at a temperature of 64 F.

The writer freely acknowledges that he is not in a position to furnish experimental data in support of this theory, but it seems quite evident that some modification of the accepted law governing the evaporation of perspiration from human beings at rest in still air is required. The foregoing is merely a suggestion as to where the line of evident perspiration may lie and Fig. 5 shows its possible location upon a psychrometric chart.

ANDREW C. EDGAR

An Appreciation

On February 13, 1933, our Society and the whole heating industry suffered a loss of such magnitude that as yet it cannot be fully measured.

Andrew C. Edgar, our beloved fellow member and friend, passed to his reward. He was a Charter member of the A. S. H. V. E., was present at the first regular annual meeting and holds the distinction of being the only member who attended every one since that time. In thirty-nine years he was never absent from an annual meeting. Such loyalty to our Society is rare, indeed, and most exceptional.

While we all honored "Andy" for his faithfulness to our Society, it was as a kind friend with a warm sympathy that he is enshrined in our hearts. It was my privilege, during the last fifteen or more years, to know him well. I saw his ability, his influence exerted unselfishly, not once but many times, for the good of his fellow men.

He was the most constructive force at work in our industry to bring into harmony the interests of the contractor, jobber and manufacturer. Toward this goal he labored for many years, always using his delightful sense of humor, his fairness of viewpoint, his forcefulness of character, his ability and his characteristic frankness.

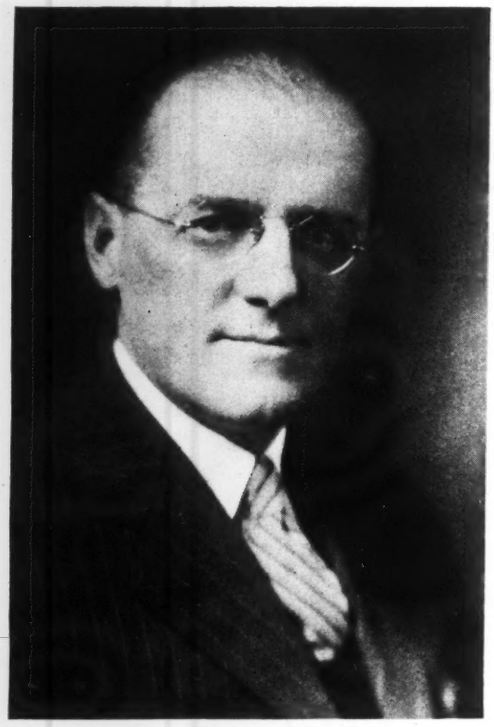
He was a delightful companion on any occasion, being a great student of human nature and having trained his mind to an unusual degree by good reading. In retrospect I can think of nothing more enjoyable than to linger over the luncheon table in the old Manufacturers' Club in Philadelphia with "Andy" present and let the talk and imagination wander from one subject to another—religion, travel, business, politics or whatever came to mind. He was informed and had an interesting viewpoint on all human relations.

He was charitable to a degree, I suspect far beyond his means, for he was the thoughtful one of our crowd, always doing his duty first and then kind enough to gently remind us of ours.

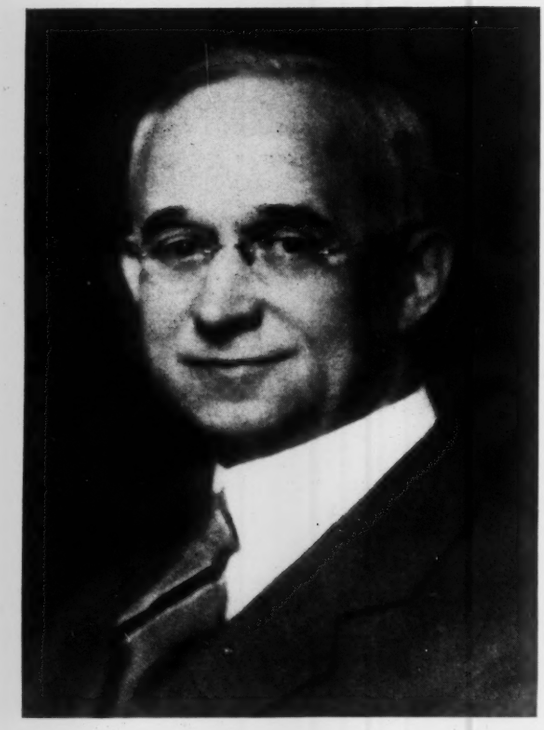
To know him was to have a real affection for him. It would be selfish, realizing our loss, to wish him here when he has gone on to his reward, but we shall miss him, and seldom, if ever again, shall we look upon his equal.

March 1, 1933. THORNTON LEWIS

Officers and Council Members



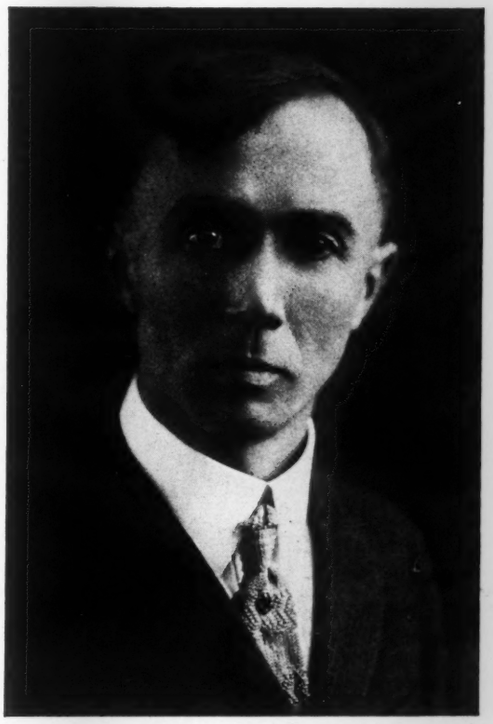
W. T. Jones
Boston, Mass.
President



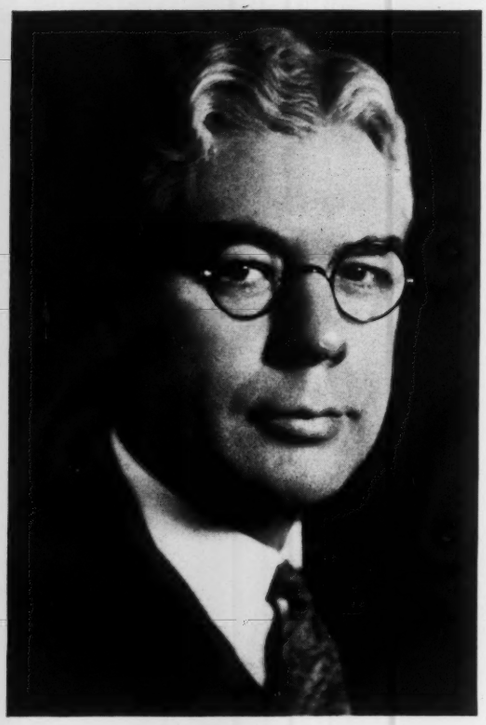
C. V. Haynes
Philadelphia, Pa.
First Vice-President

John Howatt
Chicago, Ill.
Second Vice-President

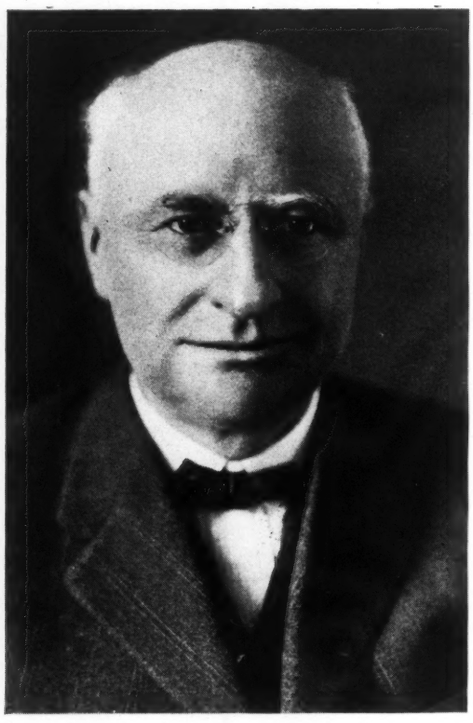
D. S. Boyden
Boston, Mass.
Treasurer



F. B. Rowley
Minneapolis, Minn.
Chairman Advisory Council



R. H. CARPENTER
New York, N. Y.



J. D. CASSELL
Philadelphia, Pa.

Members of the Council for Three Years

F. C. McINTOSH
Pittsburgh, Pa.

L. W. MOON
St. Louis, Mo.

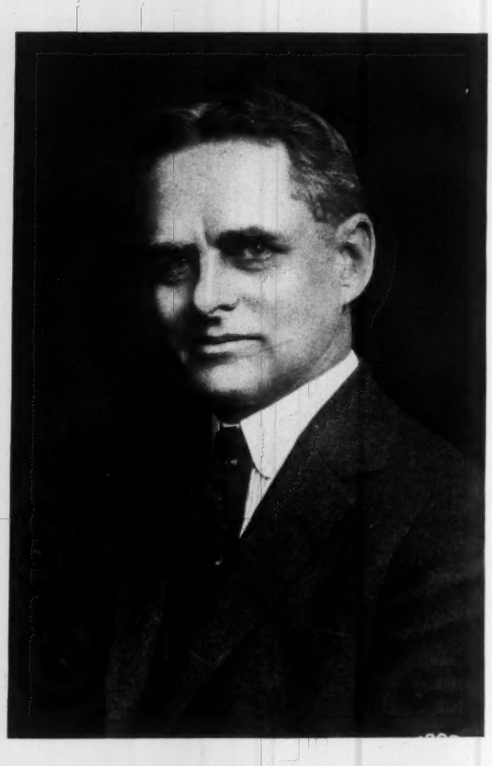
F. E. Giesecke
Austin, Texas

G. L. Larson
Madison, Wis.

Members of the Council for Two Years

J. F. McIntire
Detroit, Mich.

W. E. Stark
Cleveland, Ohio

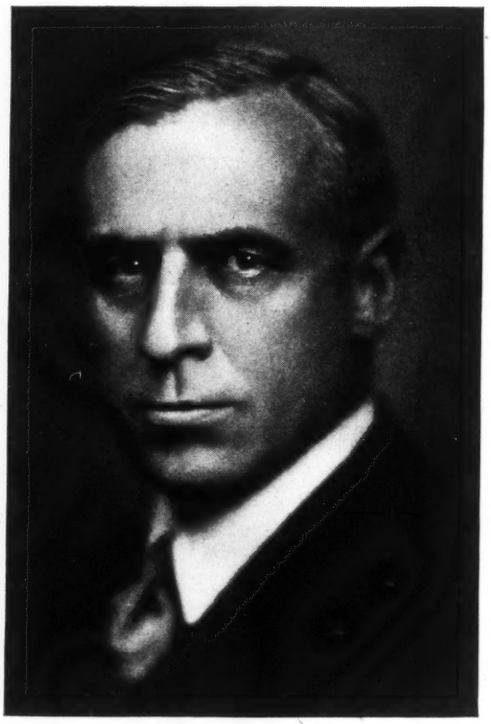


E. K. Campbell
Kansas City, Mo.

E. O. Eastwood
Seattle, Wash.

Members of the Council for One Year

Roswell Farnham
Buffalo, N. Y.



E. Holt Gurney
Toronto, Ont.

Members of the Committee on Research Elected 1933

ALBERT BUENGER
St. Paul, Minn.

S. H. DOWNS
Kalamazoo, Mich.

HOMER R. LINN
Chicago, Ill.

H. N. KITCHELL
Cincinnati, O.

PERRY WEST
Newark, N. J.

E. N. SANBERN
Philadelphia, Pa.

Local Chapter Reports

Illinois

March 13, 1933. The March meeting of the Illinois Chapter was preceded by the usual dinner in the Old Town Room, of the Hotel Sherman, with Pres. J. H. O'Brien presiding and a splendid attendance of 102.

The following resolution in memory of W. A. Pope was presented by H. M. Hart and approved by standing vote:

Whereas, William A. Pope, a member of the AMERICAN SOCIETY OF HEATING AND VENTILATING ENGINEERS, was also a charter member of the Illinois Chapter, and

Whereas, he was outstanding in the field of heating, ventilating and power piping, and

Whereas, he was looked upon as one of the leaders in the field in which we are all engaged, and

Whereas, his spirit passed on to eternal life on February 17, 1933, be it

Resolved, that this Chapter, in meeting assembled on Monday, March 13, 1933, do take recognition of his achievements and record our feeling of personal loss in his passing from our midst, and be it further

Resolved, that our regrets at his going be spread upon our records, and that a copy be forwarded to the widow and family, that they may know with what high esteem we held him.

R. M. Getschow, R. E. Moore and E. E. Bolte were appointed to act as tellers to count the ballots for members of the Nominating Committee.

A communication was received from John Howatt, a member of the A. S. H. V. E. Council, which informed the Chapter of an invitation to the Society from the *American Oil Burner Association* to maintain a booth during their meeting and exhibit at the Hotel Stevens, June 10-16. A motion was approved to refer this invitation to the Board of Governors for consideration.

A letter was read from the *American Society for Testing Materials* which contained an invitation to A. S. H. V. E. members to attend their annual meeting and exhibit to be held June 26-30 at the Stevens Hotel.

A notice was also received from the *Western Society of Engineers* which called attention to a proposed bill to register professional engineers in the state.

The month's regular subject, Ten Minutes of Something New, was in the competent hands of S. I. Rottmayer, who had prepared a comprehensive study of the experiments on Summer Cooling in the Research Residence at the University of Illinois. His paper contained considerable data on the cooling methods used and the results obtained. Interesting comparisons were made between the performance of the cooling plant in the University of Illinois residence and that of a plant in Detroit.

Homer Linn then introduced C. A. Donnel, Principal Meteorologist in Charge, U. S. Weather Bureau, Chicago, who spoke on Forecasting the Weather and illustrated his talk with a film entitled, Back of the Weather Forecast. Mr. Donnel gave a brief description of the manner in which great centers of turbulence are formed in atmosphere and explained their movements across the continent. He also spoke of the work of weather observers stationed all over the United States and Canada and how their data is distributed and charts are made, which make possible weather forecasts.

A third speaker was W. D. Mitchell, People's Gas, Light and Coke Co., whose subject was The Application of Gas to Water Heating in Large Office and Apartment Buildings. Mr. Mitchell stressed the importance of making a careful selection of the burner and its method of application to each individual installation.

The meeting was then open for the discussion of the three papers.

President O'Brien announced the results of the election of the Nominating Committee, reported to him by the tellers, as follows: J. J. Aeberly, C. W. DeLand, R. E. Hattis, J. J. Hayes, E. P. Heckel, John Howatt and S. R. Lewis.

Kansas City

March 13, 1933. An enjoyable meeting of the Kansas City Chapter was held at the Newbern Hotel, when 45 members and guests were present to hear a very interesting and instructive lecture and demonstration by R. J. Thompson on F12 (freon).

At this time the customary educational feature of the meeting was a paper presented by Sidney Pines on Recent Developments in Steam Heating Equipment.

It was learned that one of the Chapter's oldest, most active and most beloved members, L. W. Millis, was to celebrate his Golden Wedding Anniversary on March 15 and it was unanimously decided to hold a party in his honor at the home of E. K. Campbell. It is expected that a rousing good time will be enjoyed by all of the Chapter members and their wives who can be present.

A topic, which furnished considerable discussion at the meeting, was the carbon monoxide tests being made in Kansas City with the aid of the Chapter, Prof. A. H. Sluss and Mr. Campbell.

An old friend, "Shorty" Lewis, was present as a guest and everybody was glad to see him.

All of the members present felt that the meeting was one of the highlights of the season, as a splendid spirit was displayed and much benefit was received according to the report of Secy. D. D. Zink.

February 17, 1933. An event which marked history in Kansas City by bringing an attendance of 500 was the Joint Meeting of the Chapters of the A. S. H. V. E., the *A. I. E. E.* and the *A. S. M. E.*, held at the Kansas City Power and Light Building in an air conditioned auditorium known as Thomas A. Edison Hall. Members of all engineering and technical societies, architects and members of the real estate board had been invited.

Samuel R. Lewis, consulting engineer of Chicago, was the principal guest speaker and was present by invitation of the Kansas City Chapter of the A. S. H. V. E. Mr. Lewis presented a very interesting paper on Air Conditioning for Human Comfort, a subject of much common interest today.

During the afternoon the Presidents of the Chapters of the *A. S. M. E.*, the *A. I. E. E.* and the A. S. H. V. E. formed a committee to entertain Harry P. Charlesworth and S. R. Lewis, the guest speakers, and showed them through the new Art Institute which contains one of the most complete and modern air conditioning systems in Kansas City.

A dinner was held in honor of the speakers by the *A. I. E. E.* and was attended by the officers and others from the *A. S. M. E.* and A. S. H. V. E. local Chapters.

Massachusetts

March 20, 1933. The March meeting of the Massachusetts Chapter was held at 7:00 p. m. at the Harvard School of Public Health and was attended by 65 members and friends.

Albert J. Nesbitt of John J. Nesbitt, Inc., presented a paper on A Logical Basis for Determining the Volume of Air to Be Circulated in Classroom Ventilation. Mr. Nesbitt recited the results obtained from comprehensive studies made in a class room of a Philadelphia School and illustrated these results by lantern slides.

At the close of the address a lively discussion of the subject matter was interrupted only to allow the medical fraternity present to present to the meeting some of their achievements.

Philip Drinker presented Dr. Behnke, who showed and described a rubber lung to be worn by occupants of a sunken submarine when venturing an escape to the ocean surface.

A kindly offer was made by Dr. Behnke to allow any candidate, who volunteered, to experience a new sensation in a basement tank while clothed with a rubber lung. There was no

applicant for such honor but all present were deeply interested in much of the basement equipment afforded by the School of Public Health.

Announcement of the April meeting was made, the same to be a Noon meeting on April 10, when Dr. Howard S. Gill of the State Penal Institution will address the Chapter members.

The March meeting, presided over jointly by Pres. F. R. Ellis and W. T. Jones, was a decided success. The attendance was no doubt augmented through the efforts of E. Q. Cole, who has divided the membership into a group of competing teams for an attendance record.

February 13, 1933. Members of the Massachusetts Chapter of the A. S. H. V. E. were hosts to the *Boston Society of Civil Engineers,* the Boston Section of *American Society of Mechanical Engineers,* the Plant Engineers' Club and the State Engineers at dinner at 6:30 in the Engineers Club, Boston, with Pres. F. R. Ellis presiding.

As the usual routine business had been dispensed with Charles P. Howard, a guest and very capable speaker was introduced. Mr. Howard is chairman of the Massachusetts State Commission of Administration and Finance, which passes on all state expenditures and, by its systematic guidance and control, has saved the tax payers hundreds of thousands of dollars. Where the Tax Dollar Goes was the subject of Mr. Howard's address.

Few of those present knew how Massachusetts ranked with the states in percentage of tax increase. Mr. Howard displayed a chart of a Federal Survey showing the percentage of increase in government cost for each state, during the period from 1915 to 1930. This showed increases ranging up to 1200 per cent with Massachusetts substantially the lowest with an increase of only 132 per cent. An itemized statement of comparative costs for various functions of the State Government was heard with interest. Mr. Howard also explained that the entire proceeds of the State Income Tax are turned back to the cities and towns on a pro rata basis of the real estate valuation.

Having been educated as an engineer, Mr. Howard was in tune with his audience and the meeting proved a very good departure from the usual style of program.

Minnesota

March 13, 1933. The Minnesota Chapter of the A. S. H. V. E. held their March meeting at the plant of the Minneapolis-Honeywell Regulator Co. and started with an inspection trip at 5:15 p. m. Dinner was served at 6:30 and at its conclusion the regular business meeting was held.

Pres. W. F. Uhl called upon N. D. Adams, as special chairman of arrangements, for a progress report on the joint meeting with the Wisconsin Chapter to be held April 24, at LaCrosse, Wis., as guests of the Trane Co. An outline of the program for the day was given, with a trip through the company's plant at 10:30 a. m. to be followed by luncheon at noon and golf in the afternoon.

Dinner will be served at 6:30 p. m., after which a series of papers will be presented. At the conclusion of the business meeting, a stag party is to be held with both Chapters taking part and members of the Minnesota Chapter will return to Minneapolis on Wednesday morning. William McNamara, in the absence of R. N. Trane, extended the invitation to meet at LaCrosse and stated that every effort would be made to provide an entertaining time.

Albert Buenger and E. F. Jones, of the Attendance Committee, outlined the cost of the trip and requested every member to go if at all possible. Further details will be announced later.

G. D. Kingsland was introduced by President Uhl as the speaker of the evening and presented a paper on the Theory of Self-Contained Radiator Valves, illustrated by slides and models of valves. Mr. Kingsland's paper was an excellent one and depicted the development work which has been carried on, resulting in the production of the present-day radiator control valves.

Sixty-nine members and guests were present and many participated in the discussion.

Pacific Northwest

February 23, 1933. With Pres. C. F. Twist presiding, a meeting of the Pacific Northwest Chapter was held at the Edmond Meany Hotel and, following dinner, the members and guests had the pleasure of hearing two interesting speakers.

Mr. Gebhart gave an instructive talk on pipe corrosion problems which are met with in the Pacific Northwest. Methods of coating piping systems by the treatment of steam leaving central station plants and means employed to determine the nature of treatment needed for each particular problem were described in detail.

The second speaker was Worth Goss, of Seattle, who told of a new refrigerating unit for air conditioning work, which has no moving parts and requires hot water or steam as the motivator of its Btu absorption performance.

The subjects, which were in no way related to each other, constituted an entertaining program and were discussed at length by the members and guests, says the report of Secy. S. D. Peterson.

Philadelphia

March 9, 1933. Following dinner at the Engineers Club Dining Room the members and guests adjourned to the Auditorium, where Pres. M. F. Blankin called the March meeting to order.

Secy. W. R. Eichberg read the minutes of the February meeting and the Treasurer, J. H. Hucker, gave a monthly statement, both of which were approved.

F. C. Hibbs, chairman of a Special Committee, read a well prepared resolution on the death of one of the Chapter's Life Members, H. D. Kellogg, which was ordered spread upon the Minutes.

An eulogy to A. C. Edgar, another Life Member who had recently passed away, was read by J. D. Cassell and this, likewise, was ordered filed with the Minutes.

Out of respect to the memory of Messrs. Kellogg and Edgar, President Blankin asked the members to stand in silent meditation for one minute.

The Meetings Committee then took charge and the speaker, J. H. Hucker, was presented. Mr. Hucker gave a most interesting and ably prepared paper on Atmospheric Dust and Air Cleaning Devices, which was well received. A discussion followed during which Benjamin Adams explained how the ash from power plants using powdered fuel is filtered.

President Blankin requested reports from several committees after which the meeting adjourned.

February 9, 1933. The regular meeting of the Philadelphia Chapter was held in the Engineers Club at 6:30 p. m. and, following dinner the members and guests assembled in the Auditorium, where Pres. M. F. Blankin called the meeting to order and thanked the members for their confidence in electing him President.

The minutes of the previous meeting, read by the Secretary, and the treasurer's report were approved.

The names of committee members and their respective chairmen, appointed by President Blankin, were announced and the remainder of the evening was then given over to the technical program.

Members of the *American Welding Association* were guests at this meeting, as the program was of mutual interest.

A. C. Caldwell, who had been very active in securing the speakers, introduced them, first presenting Robert Daniels who read a paper on Arc Welding of Pipe. At the conclusion of Mr. Daniel's talk, Fred J. Maeurer spoke on the Economic Advantages of Welded Piping in the Home. Both papers were presented in a very able manner and without friction, although one

speaker advocated electric welding and the other acetylene welding.

Following a general discussion, J. D. Cassell expressed the appreciation of the Chapter to Messrs. Daniels and Maeurer.

Pittsburgh

February 13, 1933. Sixty members and guests were in attendance when Vice-Pres. P. A. Edwards called the meeting of the Pittsburgh Chapter to order in the U. S. Bureau of Mines.

The minutes of the meeting held in January were read and approved and H. B. Orr, Treasurer, submitted his report, which was accepted and ordered filed.

L. B. Pittock, chairman of the Program-Publicity Committee stated that it was quite possible that W. T. Jones, Boston, President of the A. S. H. V. E., would be the speaker at the March meeting and that the committee had prospects of several other fine speakers for Chapter Meetings.

Pres. G. S. McEllroy presented the Chapter's guest and speaker, T. Napier Adlam, Bethlehem, Pa., a member of the A. S. H. V. E., the *British Institute of Heating and Ventilating Engineers* and the *A. I. P. I.*, who addressed the meeting on Radiant Heating. Mr. Adlam, who was the assistant of A. H. Barker in England in 1908, when Mr. Barker first introduced the radiant method, is an authority on this type of heating, having designed and built many installations. He traced the history of the radiant method of heating from the time of the early Roman Baths down to the present day, illustrating his talk with slides and pictures. Radiant heating was considered from both the engineering and the physiological standpoint and various mechanical devices were exhibited.

That Mr. Adlam's talk was greatly appreciated was evidenced by the enthusiastic and full discussion by the members and guests at its conclusion. Mr. Adlam was tendered a vote of thanks by those present and the meeting was adjourned at 10.45 p. m.

St. Louis

March 1, 1933. The St. Louis Chapter held its March meeting and dinner at Benish Restaurant with 18 members and guests present.

After the minutes of the previous meeting had been read and approved, reports of various committees were received and the treasurer reported a balance on hand as of March 1, in the amount of $331.19.

Paul Sodemann, chairman of the Membership Committee, read the application received from G. B. Rodenheiser, instructor in heating and ventilating at the David Ranken Trade School.

The chairman of the Program Committee, L. Walter Moon, presented a tentative schedule of papers arranged for the year and then introduced C. R. Davis, Secretary of the Chapter, who gave a paper on Pneumatic Control Temperature Regulation, which was followed by four reels of motion pictures.

There being no further business, the meeting was adjourned.

Western New York

March 13, 1933. This was the first meeting of the Western New York Chapter to be held under the new administration with Pres. D. J. Mahoney in charge. The meeting was held as usual at Gandy's and was very well attended.

The following appointments were announced by President Mahoney: Program Committee—M. C. Beman, *Chairman*, W. F. Hirschman, W. B. Maloney and F. H. Sharp; Entertainment Committee—W. F. Johnson, *Chairman*, Joseph Davis and P. S. Hedley; Membership Committee—J. J. Yager, *Chairman*, S. C. Stacy and B. C. Candee.

The members were then privileged to hear first hand news of the Cincinnati Meeting from the toastmaster, L. A. Harding.

The speaker of the evening, J. W. Spencer, was introduced and, in his talk on Refrigeration in the Air Conditioning Industry, gave a complete discussion of the fundamentals of cooling water by means of steam ejector refrigeration. His presentation of comparative costs, typical installations and operating results proved beneficial to everyone.

After a lively discussion of Mr. Spencer's talk, the meeting was adjourned with the reminder that everyone should be present on the occasion of Pres. W. T. Jones' visit to the Chapter on April 3.

Century of Progress Plans

An announcement from J. H. O'Brien, president of the Illinois Chapter of the Society, gives detailed information about the activities planned for Engineering Week, June 25 to 30, during the Century of Progress in Chicago. The Chapter's Committee on World Fair Activities consists of Robert E. Hattis, J. J. Hayes and Charles W. DeLand.

It is estimated that Engineers Week at the World's Fair will attract from 10,000 to 15,000 engineers who will visit Chicago to attend the meetings of the various Engineering Societies, spon-

Grand Circus Park, Detroit

Semi-Annual Meeting Dates Selected

The invitation of the Michigan Chapter to hold the Semi-Annual Meeting 1933 in Detroit was accepted by the Council and the dates selected are June 22, 23 and 24.

L. L. McConachie is General Chairman of the Committee on Arrangements and anticipates a large attendance. Headquarters for the meetlng will be at the Hotel Statler where technical sessions are to be held each day. Committees are now being organized to arrange the entertainment program.

sored by the *Western Society of Engineers, A. S. C. E., A. I. E. E., A. I. M. M. E.*, and *A. S. M. E.*

Engineers Day at the Fair will be Wednesday, June 28. None of the participating organizations will hold sessions on that day and all delegates will be urged to attend the special program to be held at the Exposition Grounds. The engineers group will assemble at a central point and then proceed to the various special exhibits. A luncheon program has been arranged and the inspection tour will be continued in the afternoon. A monster banquet for engineers will be held at the Stevens Hotel during the evening where eminent scientists and engineers will deliver short addresses.

A special badge designed for the occasion will be issued to all groups participating in Engineers Week and the individual groups will be identified by different colored ribbons.

The Chicago Engineers Club, 314 S. Federal St., has extended an invitation to members of the A. S. H. V. E. visiting the Century of Progress to enjoy all privileges of that Club as a member during their visit to Chicago. Guest cards will be issued upon proper identification at the Club. This privilege will also permit the use of rooms at the Union League Club which practically adjoins the Engineers Club.

A general program will soon be issued showing the time and place of all events of the participating Societies.

Obtaining Unemployment Relief

Judging from the correspondence received at Headquarters of the National Engineering Societies it is apparent that many unemployed engineers throughout the United States are unaware that various forms of relief are available in their own communities. Practically every state, county, and city has raised or appropriated funds to provide for the relief of the unemployed. These funds are being expended in various ways.

Experience during the past months indicates that all engineers out of work and in need of assistance should first acquaint themselves with the local method of providing relief. This may be done by getting in touch with any of the following persons in their community: (1) officers of local sections of national engineering societies, (2) officers of local engineering clubs, (3) the City Engineer, or (4) the County Engineer.

If the member is so located as to be unable to reach any of the persons mentioned, a letter to the Secretary of the Society will bring suggestions as to what seems to be the next best procedure.

Plan Engineering Council for District of Columbia

At a meeting in Washington, D. C., March 7, D. C. Walser, President of the *Washington Society of Engineers* presided at a meeting of thirteen representatives of engineering societies who gathered to informally discuss the question of forming a Council of representatives of engineering and allied technical organizations of the District of Columbia to be affiliated with the *American Engineering Council* and to represent and coordinate the interests and activities of these organizations in the District of Columbia.

L. W. Wallace, of the *American Engineering Council,* addressed the meeting and spoke on the benefits to be derived by such an organization and outlined the activities of the State Engineering Council.

Messrs. McDaniel, Warrington and Amadon were appointed on a committee to study the subject of by-laws, representation and to propose a name for the Council.

T. H. Urdahl, consulting engineer, was the A. S. H. V. E. representative at the meeting and reported his observations to the Council of the Society.

San Francisco Engineers Discuss Air Conditioning

An Air Conditioning Conference sponsored by the San Francisco Section of *A. S. M. E.* was held February 9 and 10, at University of California, in Berkeley and a group of 16 papers was presented. Prof. B. M. Woods was General Chairman and a member of the A. S. H. V. E., W. E. Leland, was Vice-Chairman.

The papers presented included the following:

Basic Theory of Air Conditioning by L. Washington.

The Psychrometric Chart and Its Use by C. R. Dodson.

Physiological-Psychological Basis of Comfort by C. W. Brown.

Analysis of Cooling Fundamentals by W. S. Weeks.

Cooling with Ice in California Valley Summer Weather by H. L. Lincoln.

Insulation and Heat Capacity in Relation to Heat Transfer by L. M. K. Boelter

Analysis of Los Angeles Weather by L. J. Rich.

Medical Aspects of Air Conditioning by A. H. Rowe.

Design Procedure for Heating and Cooling Installations by W. E. Leland.

Air Filtration by F. W. Kolb.

Air Infiltration through Windows by V. H. Cherry.

Cooling Rural Homes—A Study in Progress by B. M. Woods.

Sun Effect and Surface Temperatures by A. O. White and D. O. Rusk.

A Program of Research on Heat Transfer in Unit Coolers by G. R. MacPherson.

Comfort Cooling Problems and the Rural Home by W. H. Foxwell.

Industrial Air Conditioning by Natural or Gravity Ventilation by L. Y. White.

P. S. Lyon with G. E.

P. S. Lyon, formerly chief engineer for the Hall Electric Heating Co., Inc., 1429 Walnut St., Philadelphia, Pa., is now associated with the General Electric Co. in the Air Conditioning Department, at 120 Broadway, New York City.

Professor Morrill Dies

Society members and friends of Prof. Raleigh D. Morrill will be saddened to learn of his death on March 11 at the home of his uncle, F. C. Avery, with whom he resided, at Overbrook, Belltown, Conn. Professor Morrill was a nationally known research engineer on refrigeration and had been professor of Mechanical Engineering at New York University since 1926.

A native of Vermont, where he was born at Strafford, on May 1, 1885, he was the son of the late Henry A. Morrill and of Mrs. Clara A. Morrill, his only survivor, a brother, Raymond Morrill of Randolph, Vt., having died three weeks ago. He received the degrees of B.S. in M. E. and E.E. from the University of Maine and M.M.E. from the University of Minnesota. He served from 1918-1923 as professor of Electrical Engineering at Norwich University, Vermont, and as assistant professor in Mechanical Engineering at the University of Minnesota from 1924-1925. In addition to his faculty duties, Professor Morrill also did research work for the Popular Science Institute, New York City, from 1926-1929.

In 1928 Professor Morrill became a member of the A. S. H. V. E. and was instrumental in organizing the first Student Section of the Society at New York University, acting as Faculty Adviser. He was a member of the *A. S. M. E.*, the *A. S. R. E.* and recently was appointed to the National Committee for Standardizing Refrigeration Performance Tests.

As a result of his many years of experimental and research work, he had prepared a number of treatises upon the subjects of steam engines, steam turbines and thermo-dynamics, which he had planned to publish.

He became ill last fall, but continued his work at New York University until he received a leave of absence for the second term.

He was engaged to Miss Ruby B. Wilbur, of Old Greenwich, Conn., an instructor in the Stamford High School, and had planned to be married at the end of the present school year.

Funeral services were held on the afternoon of March 13 from the residence of Mr. Avery, with interment taking place in the Old Greenwich Cemetery.

CANDIDATES FOR MEMBERSHIP

The Constitution of the Society as now amended, requires the following mode of procedure in voting on applicants for membership in the Society. All applications for membership are to be sent to the Secretary and the names of applicants and their references shall be printed in the next issue of the JOURNAL of the Society or sent to the members in other approved manner as ordered by the Council. When replies are received from references, the Candidate's application shall be submitted to and acted upon by the Membership Committee as soon as possible.

When the Membership Committee has acted favorably upon a Candidate's application and assigned his grade, the Council shall vote upon the election of the proposed Candidate for membership by letter ballot. During the past month 9 applications for membership have been received and the names of these men and their sponsors are published in the following list.

Members are requested to scrutinize the list with care. The Membership Committee, and in turn the Council, urge the members to assume their share of the responsibility of receiving these candidates into membership by advising the Secretary promptly of any whose eligibility for membership is in any way questioned.

All correspondence in regard to such matters is strictly confidential, and is solely for the good of the Society, which it is the duty of every member to promote.

Unless objection is made by some members by April 15, 1933, these candidates will be balloted upon by the Council. Those elected to membership will be notified by the Secretary immediately after election.

CANDIDATES	REFERENCES	
	Proposers	*Seconders*
BARNUM, W. E., Jr., Sales Engr., York Ice Machinery Corp., Los Angeles, Calif. (*Advancement.*)	L. H. Polderman	W. H. C. Ness
	E. H. Kendall	J. M. LaMontagne
FERNALD, HENRY B., JR., Student, New York University, New York, N. Y.	A. Raffes	H. Maiman
	G. O'Hare	
HAYES, JOHN J., Office Mgr., Auburn Stoker Sales Corp., Chicago, Ill.	J. H. O'Brien	J. J. Aeberly
	H. M. Hart	E. P. Heckel
JOHNSON, CLARENCE W., Dist. Mgr., Canadian Sirocco Co. Ltd., Montreal, Canada. (*Advancement.*)	H. E. Barth	G. L. Larson
	R. G. Olson	
JONES, EDWIN, Htg. & Vtg. Engr, Watt Plbg., Htg. & Supply Co., Tulsa, Okla. (*Advancement.*)	S. E. Dibble	C. P. Yaglou
	F. C. Houghten	
LUTZ, WALTER, J. Student, Carnegie Inst. of Technology, Pittsburgh, Pa.	C. M. Humphreys	J. P. Fitzsimons
	T. F. Rockwell	
RICHMOND, JOHN, Student, Carnegie Inst. of Technology, Pittsburgh, Pa.	C. M. Humphreys	J. P. Fitzsimons
	T. F. Rockwell	
RODENHEISER, G. B., Instructor, David Ranken Jr. School of Mechanical Trades, St. Louis, Mo.	Paul Sodemann	C. R. Davis
	K. S. Wallace	G. W. F. Myers
SAUNDERS, LAURENCE PEMBROKE, Director of Engrg., Harrison Radiator Corp., Lockport, N. Y.	S. R. Lewis	A. B. B. Harrison
	H. F. Hutzel	Roswell Farnham

Candidates Elected

In past issues of the JOURNAL of the Society the names of the following men were listed as Candidates for Membership. The membership grade of each Candidate has been assigned by the Membership Committee and balloted upon by the Council. We are now instructed by the Council to post herewith, as required by Art. II, Sec. VIII, of the By-Laws, the following list of candidates elected:

MEMBERS

MOREHOUSE, H. PRESTON, Gen. Air Cond. Repr., Public Service Elec. & Gas. Co., Newark, N. J.

MYERS, FRANK L., Sales Engr., Owens-Illinois Glass Co., Toledo, O.

TORRANCE, HENRY, Pres., Carbondale Mach. Co., New York, N. Y.

ASSOCIATES

BACHMAN, AUGUST, Exec. Secy., Heating & Piping Contractors Cincinnati Assn., Cincinnati, O.

HAMILTON, JAMES E., Mgr., U. S. Radiator Corp., St. Louis, Mo.

HERSHEY, LEON A., Salesman, 11 Kneeland St., Boston, Mass.

PILLEN, HARRY A., Mfrs. Repr., Harry A. Pillen Co., Cincinnati, O.

SMITH, JARED A., Br. Mgr., Bryant Heater & Mfg. Co., Cincinnati, O.

JUNIORS

COPPERUD, EDMUND R., Minneapolis Plbg. Co., Minneapolis, Minn.

FLARSHEIM, CLARENCE A., Frigidaire Sales Corp., Kansas City, Missouri.

WEHRLE, ROBERT H., Instructor, Case School of Applied Science, Cleveland, O.

STUDENTS

JACOBSON, RUBEN A., Graduate Student, University of Minnesota, Minneapolis, Minn.

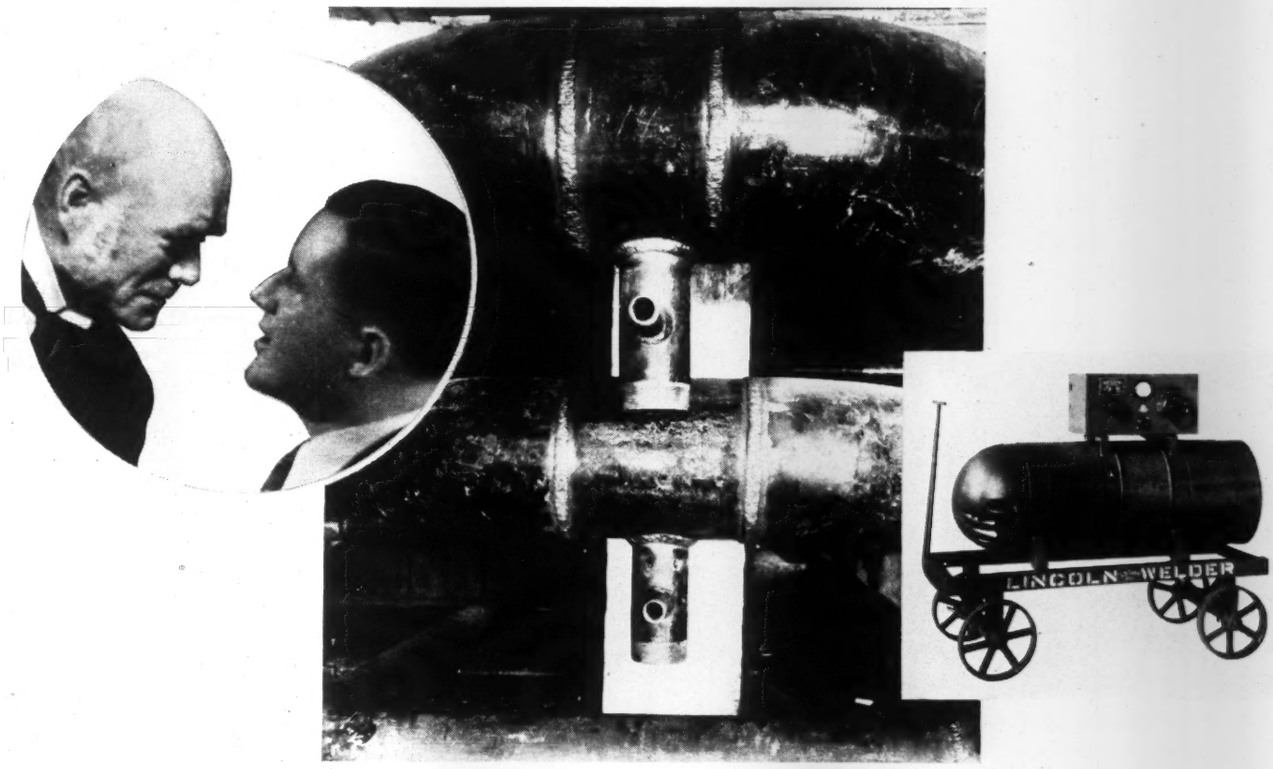
JORDAN, RICHARD C., Graduate Student, University of Minnesota, Minneapolis, Minn.

LINDBERG, ARTHUR F., Graduate Student, University of Minnesota, Minneapolis, Minn.

POWELL, KNOX A., Graduate Student, University of Minnesota, Minneapolis, Minn.

TILLER, LOUIN, Graduate Student, University of Minnesota, Minneapolis, Minn.

WIGGINS, OSWALD JAMES, Graduate Student, University of Minnesota, Minneapolis, Minn.



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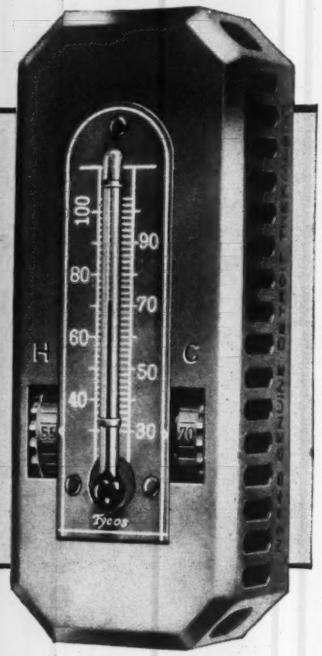

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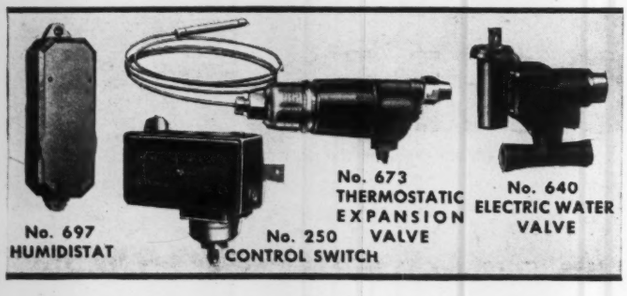


Drying—

(*From page* 190, *Editorial Section*)

drying mechanism is necessary for rational dryer design and control; secondly, a study of the mechanism leads to quantitative relationships between the moisture content and time of drying, the nature of the solid, and the drying conditions. It is possible, however, to derive an approximate relation, *for the falling-rate period,* between moisture content and *time of drying after the critical point.* Although this relation is only roughly approximate in many cases, and neither throws light on, nor requires knowledge of, the mechanism of drying, it serves as a useful guide for engineering design purposes. The relation is based on the assumption that in the falling-rate period the rate of drying is directly proportional to the water content in excess of the equilibrium water content, *i.e.,* that the rate curve in this region is straight, intersecting the moisture content axis at the equilibrium moisture content. Algebraically, the assumption is, that:

$$\frac{dW}{Ad\theta} = -C\,(T - T_E) \quad \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

where $\frac{dW}{d\theta}$ is the rate of drying, as lb water per hr, A is the wetted surface in sq ft, and C is a constant of proportionality. T represents the moisture content as lb water per lb dry solid at any time θ, and T_E is the equilibrium water content. Since the moisture contents are expressed on the dry basis, the rate of loss of moisture $\frac{dW}{d\theta}$ is proportional also to the rate of change of moisture content $\frac{dT}{d\theta}$, hence

$$\frac{dT}{d\theta} = -C_1\,(T - T_E) \quad \ldots\ldots\ldots\ldots\ldots\ldots (2)$$

The difference $T - T_E$, representing the moisture content in excess of the equilibrium moisture content, will be referred to as the *free water content*[4], since it is not possible to remove more than this amount by air-drying. Letting E' represent the ratio of the free water content at any time in the falling-rate period to the free water content at the critical point, then:

$$-\frac{dE'}{d\theta} = -\frac{d}{d\theta}\left(\frac{T - T_E}{T_C - T_E}\right) = \frac{C_1\,(T - T_E)}{T_C - T_E} = C_1 E' \ldots (3)$$

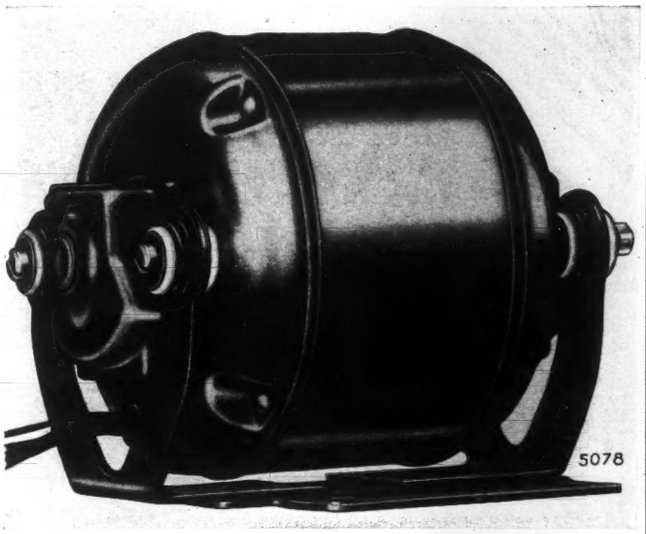
where T_C is the critical moisture content.
Integrating:

$$\log_e E' = -C_1\,\theta' \quad \ldots\ldots\ldots\ldots\ldots\ldots (4)$$

which is obtained by substituting the limits $E' = 1$ at $\theta = 0$, and $E' = E'$ at $\theta = \theta$. Since it follows that the time θ must refer only to the time of drying in the falling rate period, it is represented by θ' to distinguish it from the total time of drying, including that in the constant-rate period.

From one point of view, Equation 4 may be said to be better than the assumption on which it is based. Thus experimental data deviating considerably from the as-

[4]In wood technology the same term is sometimes used in referring to the moisture in excess of the fiber-saturation value.



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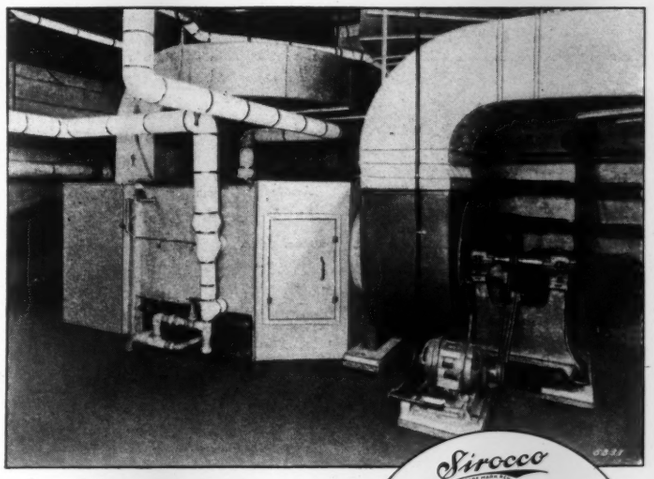

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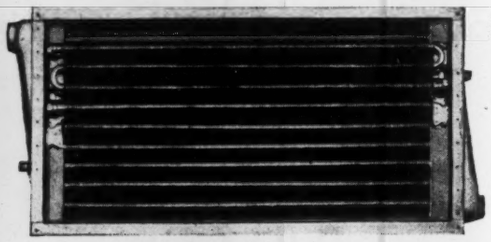

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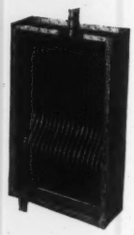

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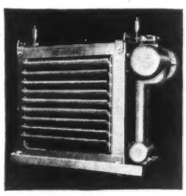

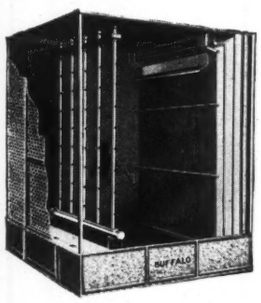

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"Limit-Load" Conoidal Fans fill a long-felt want. Having high efficiency, non-overloading power characteristics, very quiet operation and sturdy, trouble-proof construction, Limit Load Conoidal Fans are also modest in Cost. In other words, they are the finest ventilating fans we have ever built—at remarkably low prices. For every kind of ventilating work requiring centrifugal fans, "Limit-Load" Conoidals are unhesitatingly recommended. Bulletin 2884 describes features of design and construction. Ask for copy.

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sumed linear rate relation are found to follow closely the integrated Equation *4*, since on integration the irregularities in the rates tend to disappear. Equation *4* is found to be approximated in the drying of many types of materials, in spite of the fact that the linear rate relation is seldom approached.

Clearly the simplest test of Equation *4* is to plot actual drying data as log E' vs. $6'$, or as log $(T - T_E)$ vs. θ. Fig. 5 is an example of such a plot, in which a logarithmic ordinate scale is used instead of plotting log E' directly. Fig. 5 shows data on air-drying of two thicknesses of insulation board, using air at 110-120 F at a moderate velocity. Since in these experiments no constant-rate period was obtained, the ratio E of free water

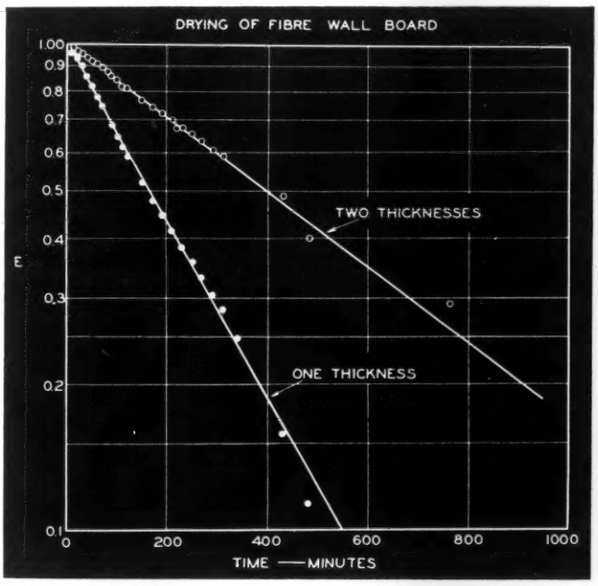

Fig. 5—Drying data on insulation board plotted on semi-logarithmic coordinates

content to *initial* free water content is plotted on semi-logarithmic coordinates against the time θ from the start of the drying process. Excellent straight lines result, and it may be noted that in this particular case the slopes are approximately in the inverse ratio of the thicknesses of the samples.

The quantitative treatment of the drying process at moisture contents above the critical is not difficult, because the rate of drying is constant except in the initial adjustment period, and the latter is usually of negligible importance. The quantitative treatments in the two regions are connected by Equation *2*, since at the critical moisture T_C, the rate is equal to the rate of drying in the constant-rate period. This is best understood by a study of the following numerical example:

Example Shows Use of Data

In a certain industrial dryer, 7 hours are required to dry a wet material from 33 per cent to 9 per cent water, dry basis. The critical moisture is 16 per cent, and the equilibrium moisture content is 5 per cent, dry basis.

Here is an Airtight Specification

Heating Engineers and Architects, who specify "Sarco Radiator Traps" outright, do not worry about "substitution". There is only ONE TYPE of Sarco Radiator Trap, made in different sizes, which are specified according to published capacities. Sarco Radiator Traps are all identical in these vital features of design:

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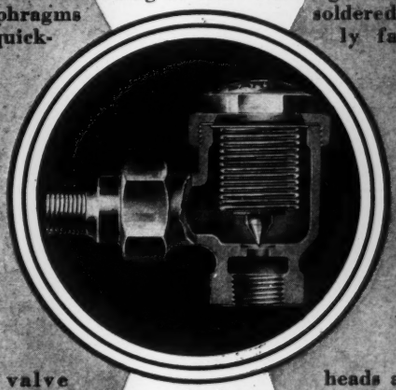

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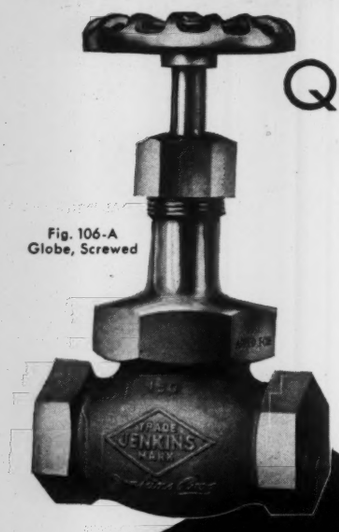

Fig. 106-A
Globe, Screwed

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Estimate the time required to dry this material from 37 per cent to 7 per cent, if the drying conditions are to remain unchanged. The initial adjustment period may be assumed negligible.

Solution: Let θ_C represent the time of drying in the constant-rate period, and θ_F the time in the falling rate period. By Equation 2 the rate of drying $\frac{dT}{d\theta}$ in the constant rate period is equal to:

$$C_1 (T_C - T_E)$$

Consequently, for the present conditions in the dryer,

$$\theta_C = \frac{(0.33 - 0.16)}{C_1 (0.16 - 0.05)} = \frac{1.54}{C_1}$$

and from Equation 4,

$$\theta' = \theta_F = -\frac{1}{C_1} \log_e \frac{0.09 - 0.05}{0.16 - 0.05}$$

$$= \frac{1}{C_1} \times 2.3 \log \frac{0.11}{0.04} = \frac{1.01}{C_1}$$

Since the total time is 7 hours,

$$7 = \theta_C + \theta_F = \frac{1.54}{C_1} + \frac{1.01}{C_1} \text{ ; whence } C_1 = 0.364$$

Under the new conditions

$$\theta_C = \frac{0.37 - 0.16}{C_1 (0.16 - 0.05)} = \frac{0.21}{0.364 \times 0.11} = 5.25 \text{ hours}$$

$$\theta_F = \frac{1}{C_1} \times 2.3 \log \frac{0.16 - 0.05}{0.07 - 0.05} = 4.68 \text{ hours}$$

and the total time required is $5.25 + 4.68 = 9.9$ *hours.*

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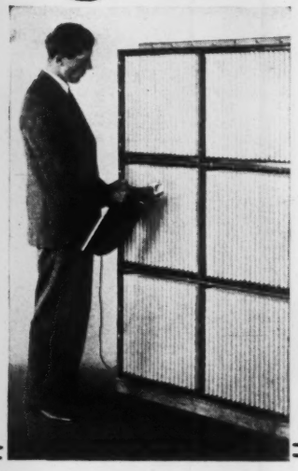

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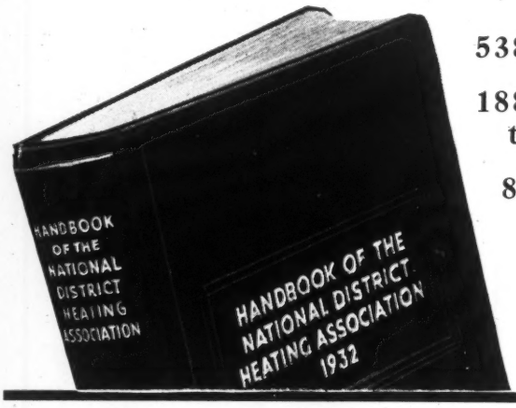

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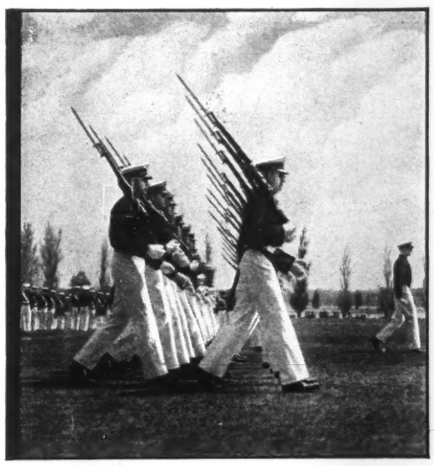

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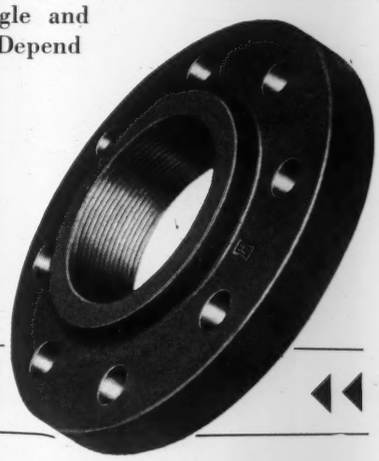

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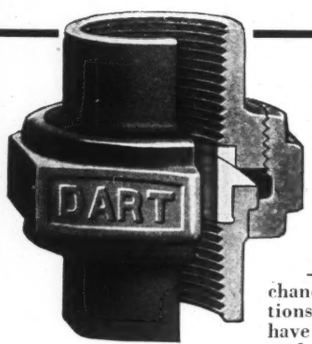

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Central Heating—

(*From page* 193, *Editorial Section*)

ing shall be carried through tunnels between the central plant and the college buildings, or shall be installed in conduits of one type or another. If tunnels are built, as has been the case in some of the larger colleges, the steam and electric conduits, and sometimes the sewer piping, may be installed therein, where they will at all times be accessible for maintenance. Tunnels of proper size also serve for easy communication between the several buildings, and if the arrangement of the buildings is compact, they offer a decided advantage in many ways.

Their cost, however, unless there are many pipes to be accommodated, will probably prove a major problem. A conduit system will usually cost but a third or even less, as compared with the cost of a good "walking" tunnel.

Much depends upon the cost of labor and materials in the local market. Reinforced concrete will usually be selected for building tunnels and some types of pipe conduits. Tunnels frequently may be so located that the top surfaces will serve as walks between the buildings.

In some locations where the ground is naturally wet, very great care must be exercised in laying any type of conduit or tunnel, in order to exclude ground water. Under drainage, not only directly beneath the conduits (as is always required) but frequently extending into the surrounding ground areas up to 30 or 40 ft on either side of the pipe lines will be necessary. Here a liberal use of agricultural tile laterals leading to a main drain to dispose of the ground water is indicated.

A clay subsoil will frequently cause a problem in drainage, and all such occurrences must be given consideration in making comparisons in cost between a tunnel and conduit construction.

Fig. 1 illustrates the arrangement of pipes in a tunnel connecting the buildings of a prominent Eastern college; Fig. 2 shows the manifold piping in a pump room.

The types of conduits for underground piping are many. The principal feature to be kept in mind is the need, as before stated, of excluding water in order to keep down operating costs.

Probably all conduit systems are flooded at times, due to heavy rainfall and the melting of snow. With proper drainage of the trenches in which the conduits are placed and a suitable type of insulation, no permanent damage should result, as the insulation will soon dry out.

Fig. 3 well illustrates a type of built-up conduit, with two tile underdrains laid in crushed stone under a concrete base; glazed cellular tile sidewalls, reinforced concrete cover and all well mopped with hot asphalt.

Fig. 4 is the end view of another form of built-up installation, showing underdrain and reinforced concrete base, with a galvanized corrugated iron shield over the pipe, which in turn is also protected on sides and top with reinforced concrete.

Glazed clay tile conduit, ranging in size from 6 to 28 in. in diameter, and in lengths 30 and 36 in., are used to a great extent in underground steam and hot-water transmission lines. They are reliable in service and will last indefinitely.

The trench work, preceding the laying of tile, is similar to the preliminary work required for built-up conduits. Care must be exercised in grading, underdraining.

Motor-driven appliances, like human beings, have hearts—strong hearts or weak hearts, depending on the quality and proper choice of the motor. For the motor is the heart, and when the motor breaks down the appliance is "dead" as far as the opinion of the user is concerned.

Who is to blame when the heart fails? Guilty or not, the manufacturer of the appliance is held responsible by the user. He is expected to avoid such troubles.

That manufacturers of equipment such as illustrated are appreciating the importance of the motor—the HEART of the appliance — is evidenced by the growing tendency on the part of motor buyers to consult Wagner before deciding on the type and rating of motor.

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and with some types of tile, in supporting the lower half beneath the roll frames with concrete, usually spaced from 12 to 15 ft. This form of tile is usually scored in the mould, and split open lengthwise on the job, and if reasonable care is exercised in marking the upper and lower halves so that they will come together after the pipes are installed, a tight joint will result. Usually the bell and lengthwise joints are filled with neat cement

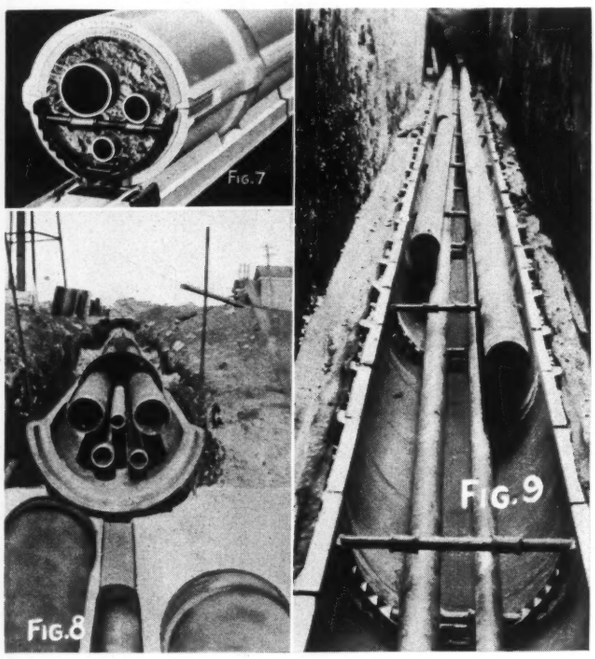

Fig. 7—Conduit obtainable with combination support and underdrain. Figs. 8 and 9—Two excellent views of conduit and pipe laying

and afterwards mopped with a hot asphalt compound.

Another type of conduit is obtainable with a combination support and underdrain for its full length; a close-up is shown in Fig. 7. Note that the longitudinal joints are of a design permitting the use of waterproofing material.

Excellent views of conduit and pipe laying are shown in Figs. 8 and 9. Note the pipe supports or "roll hangers" in both views. In Fig. 9 the evident intent is to install other pipes on the upper rolls, while in Fig. 8 a different form of guide, suitable for high-pressure steam, is employed. The near-end view of the conduit in this figure suggests the entrance to an expansion pit.

Fig. 10 is a close-up of a cast-iron conduit, or one of copper alloy metal, with underdrain, the use of which is indicated in streets or where heavy trucking is encountered.

Ultimate success in the use of any type of conduit transmission depends upon the care used in the installation, and particularly in inspection of the work as it progresses.

Underdraining *must* be provided and in many locations sump pits and automatic pumps (in duplicate) must be provided for the purpose.

In many instances it will be necessary to locate the

conduit lines near trees, in which case it is advisable to excavate the earth alongside the conduit line to the depth of the underdrains and remove the fibrous rootlets, which, in search of moisture, will enter at the open ends

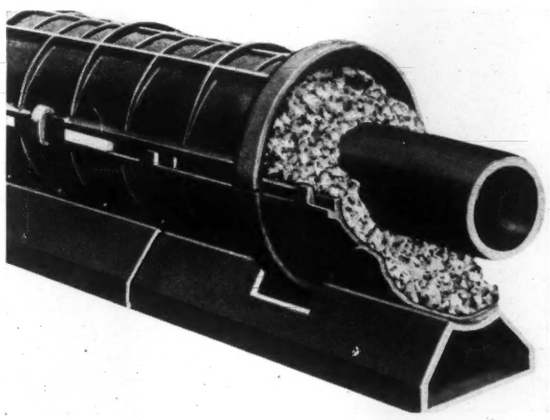

Fig. 10—Close-up of cast-iron conduit (or one of copper alloy metal) as would be used in streets where heavy trucking is encountered

of the tile underdrain and form a solid mass. It is not unusual for such obstructions to cause serious flooding of the entire conduit system, with attendant damage to the insulation and excessive waste of steam through the heating and evaporation of the ground water.

Clearing the underdrains should be attended to at stated intervals of, say, two or three years.

Editor's Note: In following installments of this article, plant equipment, piping materials, layout of the distributing system, returning the condensate, insulate, etc., will be discussed.

Brewery Piping—

(*From page* 202, *Editorial Section*)

ground of Fig. 6 and are placed by hand on the racks of the pasteurizer.

The washing of the empty bottles before they come to the filling machine is very thorough. In the bottle washer, to which steam and water is piped, the bottles pass through a solution of caustic soda and then through rinsing baths. The bottles are inverted—all automatically —after the washing is completed and rinsed by a jet of warm water which is forced up into the open mouth of the bottle. The bottles are then righted and are ready for filling. One operator does nothing but inspect the bottles for cleanliness as they pass before him on the conveyor to the filling machine.

Beer is supplied to the filling machine from the tanks in the cellar of the bottling house.

In the pasteurizer the racks of bottles move through baths of hot water thermostatically controlled to pasteurize the beer at the proper temperature to prevent further fermentation. It takes about an hour for a bottle to complete its trip through the pasteurizer. After pasteurization, the bottles go to the automatic labelling machine and from there are placed in cases for shipment. Steam and water must of course be piped to the pasteurizer.

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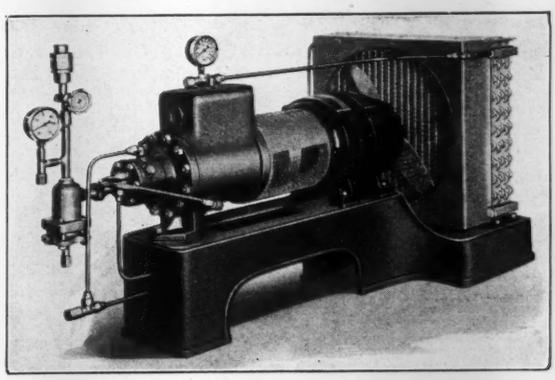

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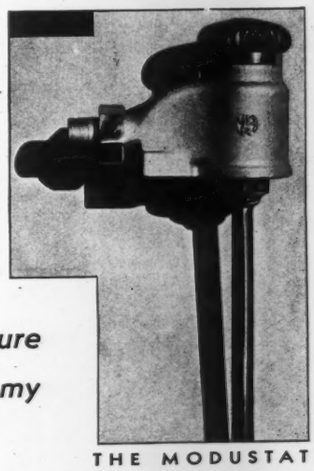

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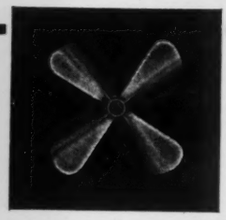

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Steam Supply Must Be Dependable

In Fig. 1 are illustrated the several steam supply mains, the exhaust line and the hot-water line for boiler feed located on the ceiling of the engine room at the Atlas brewery. These pipes are well insulated, properly supported and anchored. The 90-deg elbows and change of direction shown in Fig. 1 were provided for flexibility as trouble with expansion had been experienced. By changing the lines to the layout shown this trouble was eliminated.

As the brewing process at the Atlas plant is practically continuous, steam can be used economically for driving the refrigeration compressors, pumping water, compressing air, etc. Electrical current is also generated at the plant, a four-cylinder vertical uniflow engine direct-connected to a 200 k-va, 240-volt, 3-phase generator being provided for this purpose. Plans are in progress for installing steam flow meters to measure the steam used in these various services more accurately.

As indicated by the description of the brewing process dependability of the steam and refrigeration for a brewery must be assured and this must be considered in laying out the piping. For this reason the three Corliss-engine-driven refrigerating compressors are supplied with steam for power by three different mains from the boiler header. Another main supplies the uniflow engine. Branches are taken off these mains to supply the brew house, bottling department, etc.

Extra-strong wrought steel pipe is used for live steam mains and standard weight for the exhaust line. Welded joints are used as much as possible on alterations to the piping, and all lines are sized for expected enlargement of the plant.

There are two 100-ton and one 125-ton refrigerating compressors now installed, and space is provided and steam connections welded in for a future compressor when necessary. Steam for the entire plant is supplied by two 600-hp bent-tube boilers,

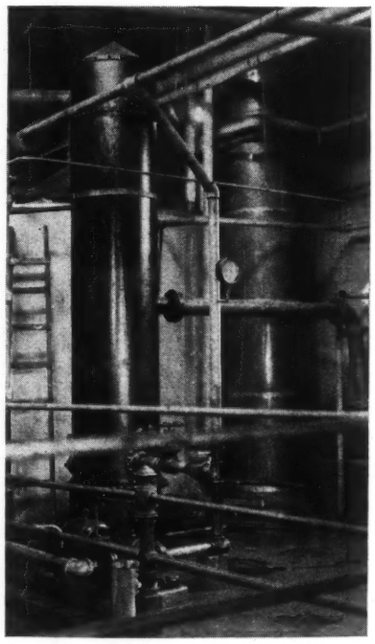

Fig. 7—Water which has been preheated in the hot-wort cooler shown in Fig. 4 goes to the tank in the background. It is then circulated through the heat exchanger, shown here, by a motor-driven centrifugal pump, where it is further heated by steam. To the right rear of this picture is the copper vent pipe from the brew kettle shown in Fig. 3 to the atmosphere

fired by chain-grate stokers, installed a few years ago as part of an extensive modernization program which is still in progress. Two of the old hand-fired fire-tube boilers are still in use for burning dried hops and other refuse. Amount of exhaust steam available for process use varies widely due to the varying refrigeration load in winter and summer.

Water Supply From Four Points

The water supply must also be dependable and for this reason it is obtained from three points from city mains, in addition to an emergency connection for supplying the boilers. This assures a water supply even under extraordinary conditions. For the most part water is pumped by a steam-driven pump to the house tank on an upper floor of the plant where it is distributed by gravity to the points of use.

In a preceding paragraph it was mentioned that cold water from the house tank flows through the hot-wort cooler (where it is heated to about 120 or 130 F) and thence to a 9,000-gal hot-water tank. The water in this hot-water tank is circulated through the heat exchanger shown in Fig. 7 by a small motor-driven centrifugal pump. This heater is supplied with exhaust steam and the water is drawn from the tank as needed for boiler feed and the brewing process. Utilizing the heat from the hot wort and the exhaust steam in this manner has effected large savings in operating costs. In summer, when large amounts of exhaust steam are available from the engines driving the compressors, the water is heated by this means to 170-180 F. Condensate from the steam used for heating water is wasted to the sewer to prevent any possibility of oil getting into the steam used in the brewing process.

Compressed Air Must Be Pure

The maximum air pressure used is 50 lb per sq in. Air is conveyed in clean galvanized iron piping.

An air compressor of novel design has just been installed at the Atlas plant. In brewing it is essential to keep oil or grease away from the beer, as the flavor of beer is very delicate and a small amount of contamination would be ruinous. A special type of water-lubricated air compressor has therefore been developed for brewery use to solve this problem. Another feature of this compressor is that a small jet of water is injected into the cylinder during the compression stroke to absorb the heat of compression.

This same principle is applied to the CO_2 compressors used for compressing the carbonic acid gas reclaimed from the fermenting and used in carbonating the beer. Of particular value is the cooling effect of the water with the CO_2 compressors as if the temperature of the gas goes too high during compression it is burned and gives an undesirable taste. With the cooling effect of the water which lubricates the compressor and which is injected as a jet it is possible to keep the temperature of the CO_2 being compressed at about the same temperature as that at which it leaves the fermenting tanks.

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